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PERFORMANCE EVALUATION OF
TRADITIONAL AND MODIFIED DISTEMPER PAINTS

Mary M. Culver

A THESIS

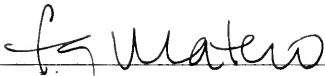
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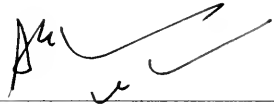
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DEDICATION

To my family.

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Introduction

Traditional distemper paints are generally known and appreciated for their soft luminous appearance. Although distempers were widely used until the first part of the 20th century, they are rarely recreated for modern restorations in the United States. Distemper paints applied in architectural settings usually consist of a glue binder with calcium carbonate as the base pigment. They are considered to be rather ephemeral in nature due to their high pigment content, and gelatin's propensity for absorbing moisture which often compromises the integrity of the paint film (distempers can usually be removed with warm water and a sponge). Flat polymer dispersion paints (commonly, but not always correctly, referred to as 'latex' paints) are often substituted for distempers in spite of their different optical and physical properties. This thesis examines the potential benefits of adding an acrylic dispersion to a traditional distemper paint formula in an effort to enhance its mechanical properties without compromising its distinct appearance

The primary reason for the predominant use of polymer dispersion paints is economics: they are durable, produce a consistent and predictable finish, and are convenient - purchased ready-to-use. In contrast, traditional distempers are considered to be much less practical. They have the reputation of being less wear-resistant and more time-consuming to apply. Distempers, which require some form of preparation, are made in smaller batches dictated by the amount to be

applied on a given day, therefore running the risk of slight variations in appearance. In addition, the viscosity of the wet distemper paint is temperature dependent, and so may require periodic adjustments during the application process. Although a traditional distemper may be less convenient to use, it should be kept in mind that there is a perceivable difference in appearance between the two types of paint.

An experimental program was implemented to evaluate the optical and mechanical properties of various matte paint formulas. The testing program was developed to address several questions about the nature of these paints. 1) Are there quantifiable differences between the optical properties of a traditional distemper and a matte polymer dispersion paint? 2) Will the addition of a stable polymer dispersion enhance the mechanical properties of a traditional distemper paint film? 3) If so, are there parameters for an optimum quantity of polymer dispersion that can be added before the optical properties become compromised?

Practical and theoretical reasons substantiate the case for preserving surviving historic painted surfaces and replicating original finishes using traditional paint recipes. The physical properties of traditional paints are often sympathetic to their substrates – for example, both distemper paints and traditional plasters are porous, breathable materials. As previously mentioned, traditional paints often have a distinct appearance that cannot be accurately reproduced with modern synthetic materials. Maintaining the physical integrity of historic buildings promotes knowledge of traditional crafts and materials through interpretation at sites where traditional paints have been conserved or replicated.

Distemper paints played a significant role in the history of interior finishes, yet relatively few examples seem to have survived, and the medium is rarely reproduced for interior restorations. It is the intent of this thesis to scientifically characterize the unique optical and physical properties of distempers and to improve their durability in an effort to encourage the use of this distinctive surface finish, when appropriate, in future architectural restoration projects.

Chapter 1

Distemper Paints

Glue-bound paints, commonly known as distemper, play an important role in the history of architectural interior surface finishes. They have been employed for decorative wall paintings as well as simple monochrome finishes. Many European and American treatises and trade journals written in the 18th century and up to the first half of the 20th century include chapters on the mixing and application of distemper paints.

According to David Hay “Distemper is a word derived from the French ‘detrempe’, meaning a preparation of opaque colours ground in water, and fixed by the admixture of size, paste, or gum.”¹ William Millar’s etymological attribution is slightly different: “Distemper, or destemper, from *tempera*, a term used in fresco painting, is applied to water-colours or pigments ground in water, beer, &c.”² In this definition there is no specific reference to a glue component. In the United States the word calcimine or ‘kalsomine’ also refers to glue paints, although usually limited to those used for architecture, rather than fine arts.³ In historical treatises distempers are

¹ David Hay, *The Laws of Harmonious Colouring Adapted to Interior Decorations, with Observations on the Practice of House Painting* 6th ed. (London: W. S. Orr and Co., 1847), 154.

² William Millar, *Plastering Plain and Decorative* (London: B. T. Batsford, 1897), 571.

³ A. J. Downing states that ‘kalsomine’ specifically refers to “...a very fine kind of earth (burned in a peculiar manner), pure white in color, and producing a more mellow and softer effect than whiting”, however, this pigment distinction (he may be referring to the use of kaolin, a white clay) for the terms distemper and calcimine was not found in any other literature. Downing, *The Architecture of Country Houses* (New York: Dover Publications, 1969 - originally published in 1850), 399.

occasionally called water-colour, whiting, and fresco, although these terms are not truly accurate. Water-colours traditionally have a gum-arabic binder, and whiting (a term commonly used for calcium carbonate pigment) is the predominant component of distemper, but just one of several ingredients. A true fresco is pigment suspended in water that has been applied to a wet lime plaster surface; upon curing the pigment particles become bound in the crystalline matrix of the plaster.

Distemper paints have several advantages over oil paint, the primary alternative interior finish prior to the 20th century. The first is economical; according to A. J. Downing in 1850 painting a room in distemper was about one-third the cost of painting in oil.⁴ The components of distemper are fairly inexpensive. The glue binder is water-based, and a relatively small amount of glue solids are needed, usually less than ten percent⁵. Distempers have a high pigment to binder ratio; however, the main pigment, calcium carbonate, has historically been one of the cheapest pigments available - indicated by its longstanding use as a filler (extender) in many types of paint. Although whiting is transparent relative to most other white pigments, the high pigment content in white washes and distempers allows the calcium carbonate to remain opaque; (the physical reasons for this are described in Chapter 2). If the paint is properly mixed, one coat could provide sufficient coverage. The short application time means that a number of rooms could be painted in a day.

Distemper paints may be applied to fresh plaster walls, which can take up to several years to cure. Oil paints cannot be applied until the curing has completed; the high alkalinity of uncured plaster

⁴ Ibid.

attacks the oil paint, contributing to premature failure of the paint layer. In addition, curing plaster continues to slowly lose moisture. Both plaster and distemper paint films are porous, the voids in the paint film allow the exchange of moisture. A paint film, such as oil, that is impervious to water can lead to failure at the interface where water has become trapped. Distempers also have the advantage of drying far more quickly than oils, which can take up to several weeks. The fact that distempers are relatively odorless (and easy to clean up afterwards) made them initially more pleasant to live with; in contrast, the scent from oil paint lingers for weeks until the paint completely dries.

Distemper paints are ephemeral, since they can often be removed with warm water and a brush or sponge - this characteristic is considered both an asset and a disadvantage. The simple removal of an existing coat of distemper prior to a subsequent application prevents layers of paint build-up.

This is most important in areas that have three-dimensional decorations such as cornices and ceiling medallions. The impermanent nature of the distemper paint surface often limited its application to ceilings, cornices, and the upper portions of walls (above the wainscoting), where it was less likely to be abraded. Downing states that distempers are inappropriate for rooms that undergo "hard usage", but that in parlors they have been known to last over eight years.⁶ The delicate surface of distemper may also account for its infrequent use on wooden elements after 1720⁷, subsequently more durable oil paints were applied to architectural details that sustain a great deal of wear such as baseboards, windows, doors and their surrounds. In addition, wood expands and contracts with fluctuations in temperature and humidity, oil paints form a more

⁵ Morgan Phillips, "A Survey of Paint Technology: The Composition and Properties of Paints," *Paint in America: The Colors of Historic Buildings*, edited by Roger W. Moss (Washington D.C.: The Preservation Press, 1994a), 240.

⁶ Downing, 399.

⁷ Morgan Phillips, "A Victorian Trompe l'Oeil: The Restoration of Distemper Paints," *Paint in America: The Colors of Historic Buildings*, edited by Roger W. Moss (Washington D.C.: The Preservation Press, 1994b), 157.

flexible film than distempers, and can generally accommodate moderate dimensional changes in the substrate.

Aesthetic reasons also account for the longstanding use of distemper paints. The high pigment to binder ratio creates a non-reflective, extremely matte appearance, distinctly different from typical oil-based paints. Historical documents and paint investigations reveal that many upper-class residences, palaces, and government buildings had distemper interior finishes despite the owner's capability to afford more expensive oil paint. Downing notes its optical distinction: "...there is no glare in kalsomine, but a softness and delicacy of tint, rarely or never seen in oil-colors"⁸.

Distempers were also appreciated for their ability to allow the pigment to dictate the paint color because color alteration by the binder is nominal. When oil paints were used, delicate colors often required the use of clearer, more expensive oils such as nut and poppy-seed oils; linseed oil (the most common oil binder) has a tendency to yellow and the paint to become translucent over time.⁹

1.1 Traditional Recipes for Common Distemper

Distemper paints contain pigment, glue, and water. Pigment imparts color, body and opacity to the paint film. Calcium carbonate (also known as; calcite, limestone, whiting, Paris white and Spanish white) is the major component of distemper pigments. A high-quality calcium carbonate pigment is recommended, such as Gilder's whiting, which is finely ground and contains no additives. Other white pigments such as gypsum, kaolin, zinc white and lead white are mentioned,

⁸ Downing, 399.

⁹The use of distempers in the fine arts is further indication of its valued appearance. Artists such as Andrea Mantegna, Albrecht Durer, and Edouard Vuillard all painted with distemper. The small quantity of paint required for their work negates cost as a deciding factor, and more durable paints were readily available. Unlike oil paintings, the pieces carried out in distemper were never intended to be varnished, to that they could be viewed from any angle without glare.

but are less economical and any superior hiding power they might provide is usually not necessary.¹⁰

Glue is the binder in the distemper paint film and water is the solvent to keep the glue in solution or in a gelatinous, spreadable state during application. The water is a volatile component, eventually evaporating and leaving the glue in a solid film that binds the pigment particles to each other (cohesion) and to the substrate (adhesion). Of the variety of glues available, animal (also called hide glue) is most often recommended. References to gelatin usually indicate animal glues in their purest form, containing nothing but the collagen proteins, and may be recommended for fine work.¹¹

Animal glue was commonly made by boiling collagen-containing materials such as hide, bone, connective tissue, or parchment (the skin of a sheep or goat). The reduced liquid was strained through a fine sieve, such as linen, then set aside until enough of the water had evaporated to create glue of the right consistency, or it was allowed to evaporate completely leaving the glue solids. The resulting glue is pale yellow and translucent. White glue may also be recommended for fine distemper work. It is considered a higher quality, colorless glue made from glove or white leather clippings and / or parchment. However, commercially made white glue may also contain some bleaching agents that may not be desirable in the paint.¹²

¹⁰ A. Ashmun Kelly notes in *The Expert Calciminer* that gypsum is prone to setting in the bucket, and that it results in "... a porous, chalky, dead surface, not at all pleasing". Zinc white has the advantage of being neutral with all pigments, whereas the relatively high alkalinity of whiting can affect some colors. Kelly, *The Expert Calciminer: A Complete Working Manual for Interior Decorators*, 2nd ed. (A. Ashmun Kelly, 1920), 9.

¹¹ Isinglass is a very high-quality glue obtained from fish (usually sturgeon); it is occasionally recommended for distemper paints that are to be used in a fine arts context or detailed decorative architectural painting

¹² According to Kelly, if alum is added to a glue size that has been bleached the presence of any residual acid will cause the glue to curdle. This can be avoided by soaking the glue solids in water, prior to making the solution. Kelly, 29.

Most 18th and 19th century treatises describe the following four-step procedure for making distemper paints or some close variation of it:

- 1) Soak calcium carbonate in water. Water is poured over dry whiting (or white base pigment), and the mixture is stirred. Enough water should be added to completely saturate the calcium carbonate (an extra inch or two above the settled calcium carbonate is sufficient). The calcium carbonate should soak for at least several hours, preferably overnight, and then any excess water may be poured off, leaving the calcium carbonate paste.
- 2) Add tinting pigment to the calcium carbonate paste until the desired color is achieved. It is often suggested that a bit of dark blue or black be added to the calcium carbonate to reduce its brightness and to minimize the tendency towards a slightly yellow cast. The pigment should not be added dry, but ground in water (or at least soaked in it), to ensure thorough wetting and more even distribution.
- 3) Prepare the glue binder. Combine glue solids with water. After soaking, the mixture is gently heated until the glue has dissolved.¹³ There is no specific ratio of water to glue solids, as the strength of glue solids may vary (although, an approximately ten percent solution of glue in water is often appropriate with modern, high-quality, hide glue solids). If the glue solution is too strong, scaling is likely to occur where the paint film becomes brittle breaking or peeling away from the substrate. If the glue is too weak, the pigment will be insufficiently adhered to the substrate and the pigment particles will be poorly bound within the paint film, making the surface extremely susceptible to abrasion and chalking.

- 4) In the final step the glue solution is combined with the tinted calcium carbonate paste while continually stirring. The pigment to dissolved glue ratio is roughly 2 parts of the tinted calcium carbonate paste to 1 part glue solution in most recipes. As a general rule, it is far better to use a smaller amount of high-quality glue, than a larger amount of lesser quality. Most treatises recommend that the final mixture be strained through a fine wire mesh to remove any remaining lumps of calcium carbonate or pigment. (The paint should not be mixed in a wooden bucket, as the wood has a tendency to absorb the glue.)

Recipes vary regarding the ideal physical state of the glue to be added to the whiting, and also the physical state of the paint upon application. Some say that the glue should be mixed with the tinted whiting paste while warm and liquid, and the paint mixture used in this thin state. Jean Felix Watin suggests in his 1785 treatise that “a good warmth helps the color to penetrate, but if it is used too hot, it makes bubbles in the work and spoils it.”¹⁴ Others say to allow the mixture to cool until it reaches the consistency of a ‘trembling jelly’ (thick enough for a brush to almost stand in) prior to application. Still others recommend letting the solution cool to a completely jellied state prior to mixing it with the whiting. In his 1897 treatise William Millar states:

In practice it is found that distemper mixed with jellied size will lay on better and make a better job than when the size is used hot. Colour mixed on the former plan works cool and floats nicely, while the latter works dry, and drags and gathers, thus making a rough ceiling or wall, and the difference in the labour required is very much in favour of the jellied state.¹⁵

¹³ If the glue is already in a gelatinous state, enough water is added to dilute it appropriately, and the mixture heated until the glue dissolves and the water is evenly distributed.

¹⁴ Jean Felix Watin, *L'Art du Peintre, Doreur, Vernisseur*, (Paris: 1785), unpublished English translation (1989), 4-5.

¹⁵ Millar, 572.

By the mid 19th century ready-mixed distemper paints were commercially available. These were dry mixes that required the addition of either a glue solution or, more commonly, water prior to being used. The problem with these and ‘home-made’ distempers is their potential lack of consistency in color, viscosity, or coverage. For this reason it was recommended that a sufficient quantity of paint be mixed to cover a contained area at a time (such as one room or at least an entire wall or ceiling), and that the work should not be interrupted until that area is complete. Once the distemper had been completely mixed it was to be used within twenty-four hours, as it would begin to set in the bucket making it difficult to produce a smooth and consistent paint film. In addition, the glue component was prone to spoiling.

Rose of Jericho, a paint manufacturer currently based in Dorset, England, currently sells a line of soft, ready-mixed, distempers. These are sold as dry mixes with instructions for adding water. The company’s trade literature contains practical information about mixing and applying distemper paints. Among their recommendations for monitoring paint quality is the following method for testing a paint mixture for proper glue content, prior to application:

It is a good plan to paint a little of the distemper on a piece of paper and to place this against the fire. If there is not enough size, the distemper will rub off; if there is an excess, it will peel off to some extent.¹⁶

Most historic treatises also suggest various additives that can be used to improve the mechanical properties of the paint, such as alum and wheat paste, these will be discussed in Chapter 3. The differing opinions regarding desired paint consistency may be due to personal preference or intended application for the paint, such as number of coats or surface topography (flat walls vs.

¹⁶ The Rose of Jericho Limited, unpublished product literature (London: no date is indicated)

elaborately sculpted plasterwork). For example, a thinner paint would be less likely to build up in the recessed areas of sculpted cornices, mouldings, and plasterwork, thus keeping the lines crisp.

Some treatises state that a single coat application is best, and should be applied in the thicker 'jellied' state. Other treatises recommend a two-coat application: in this case the first coat should contain a higher glue content (to prevent the paint from easily rubbing up) and be allowed to dry thoroughly prior to application of the top coat. In *The Expert Calciminer* Ashmun Kelly suggested applying a coat of weak glue size or strong alum water to the first coat of distemper in preparation for a second coat.¹⁷ If the application of a second coat lifts off the underlying coat, the paint should be washed off and reapplied.

1.2 Surface Preparation

Surface preparation prior to painting is essential for the successful application of distemper paints. A clean, smooth, hard surface is ideal; however, the substrate should have some texture or 'tooth' to provide a degree of mechanical bonding between the paint and underlying surface. A coating of size (most often glue) is usually recommended for plaster walls. This is referred to as 'clearcoling'. Some treatises suggest that glue should be applied while hot (therefore thinner), to ensure deep penetration. The coating of size reduces water absorption by the plaster, prevents the alkaline lime in the plaster from reacting with any of the colorants in the paint film, and provides a uniform, smooth, surface to which the paint adheres. Untreated plaster may absorb the paint more readily in some areas, and not at all in others, resulting in an uneven paint film.

¹⁷ Kelly, 2.

Rose of Jericho recommends the following method for determining the porosity of a wall:

The degree of porosity may be determined by moistening the tip of a finger and applying it to the plastered surface. If the moisture is absorbed within five seconds, a coat of clearcole (undercoat for soft distemper) should be given. If it remains wet for half a minute, a coat should not be necessary.¹⁸

A well-maintained wall should only require the original application of size, it should not be necessary to recoat the wall for subsequent repainting.

Some treatises recommend the addition of a small amount of black or dark blue pigment be added to the size to improve the resulting color / appearance of the final paint layer. Others recommend adding just enough whiting to color the size without making a completely opaque coating; the whiting might also provide some tooth, or texture, to the sized surface. *The Expert Calciminer* contains several recipes for size; the “best” is a mixture of soap, alum, and glue referred to as *SAG*.¹⁹ (Millar’s treatise recommends a similar recipe but includes the addition of whiting.) The additives in the *SAG* recipe produce a harder, more durable surface.

Kelly does not recommend a plain glue size as a preparatory layer for distemper paints, as the “calcimine will rub up the size, more or less.”²⁰

Walls can also be prepared with applications of varnish or oil paint, although these may require two coats of distemper to achieve a solid, opaque effect. Millar notes the potential problems caused by oil-based undercoats:

This stops the suction and gives a richness to the colouring; but if, the wall gets low in temperature during a continuance of cold weather, when a change takes place the condensation is so great that the water runs down in streams to the top of the skirting, and the colouring matter thereby becomes strained.²¹

¹⁸ The Rose of Jericho Limited, unpublished product literature.

¹⁹ Kelly, 19.

²⁰ Kelly, 21.

²¹ Millar, 572.

In the modern era, commercially available wall primers and sealers have proved to be appropriate undercoatings for distemper. In addition to their convenience (being premixed and ready-to-use), they have several physical advantages over glue. Acrylic paints are dimensionally stable once they have dried, whereas glue is prone to cracking and flaking, as it expands and contracts with humidity fluctuations. Glue is also prone to resolubilizing in the presence of moisture, compromising its adhesive properties. For these reasons, Brian Powell, architectural conservator at the Conservation Center (Society for the Preservation of New England Antiquities), recommends that prior to repainting walls that have a coat of glue size the glue be completely removed and the plaster walls resealed with a modern product.²²

1.3 Paint Application

The quality and shape of the paint brush is considered essential to achieve an even, smooth surface. Round brushes were used traditionally, (flat brushes were invented in the 19th century). Kelly describes the proper use of a calcimine brush:

The tips of the brush, rather than the bristles themselves, are used, and, as a workman described it, the brush is handled with a free, swinging motion, like the switching of a cow's tail in summer time. The brush must not be worked with a stiff hand, but with lightness and dexterity...²³

Rose of Jericho recommends a six inch long-haired copper-bound flat, soft, and natural hair brush.²⁴ The methods for application vary. Some suggest that the paint be applied using long strokes, always going in the same direction with slightly overlapping adjacent strokes. Painting

²² Brian Powell, "Painting Techniques: Surface Preparation and Application," *Paint in America: The Colors of Historic Buildings*, edited by Roger W. Moss (Washington D.C.: The Preservation Press, 1994), 225.

²³ Kelly, 2.

over strokes entirely is not recommended, as the first paint layers will be picked up by the brush, disrupting the smooth texture. If a second coat is to be applied, the brush strokes should be made perpendicular to those of the first (e.g.: first coat - vertical strokes, second coat - horizontal strokes). Alternatively, the paint could be applied by using brush strokes going in every direction. It appears that this latter method is the more modern (1872) approach. According to Gardner in *How to Paint*:

It was the practice of painters until of late years, to lay distemper colors evenly, one way only, as in oil painting; but the present method is to pass the brush in every indiscriminate direction, leaving it in that state which it is considered gives it a more solid appearance. A more recent method for obtaining the like object is called stippling. The surface is lightly struck with the end of a large hog's-hair brush, with a perfectly flat face and conveniently shaped handle.²⁵

Rose of Jericho also states in their product literature that distempers, if thinned down, can be applied by spraying.

The application process should begin in a corner of the room furthest away from the door, probably to avoid premature drying brought on by drafts. Kelly recommends working in 2' - 3' vertical strips. He notes that others suggest 1' - 1 ½', but this narrower working area is only necessary in very warm weather, or if the surface is especially absorbent.²⁶

During distemper application the immediate environment should be controlled if possible, doors and windows should be kept shut to minimize air circulation within the room. This increases the working time of the paints, preventing brush strokes from drying before adjacent strokes are applied which would leave raised laps. Once the entire surface has been painted, windows and

²⁴ Rose of Jericho Limited, unpublished product literature.

²⁵ F. B. Gardner, *How to Paint: A Complete Compendium of the Art* (New York: Samuel R. Wells, 1872), 60-1.

²⁶ Kelly, 3.

doors should be opened. At this point, the more quickly and consistently the distemper surfaces dry, the more likely they'll maintain an even appearance. Dark tints are especially prone to spotting from inconsistent drying. The optimum atmospheric conditions are clear weather "neither warm nor cold"; and it is not advised to paint with distempers in wet weather. If painting must be done in extremely warm weather, or other conditions that cause the paint to dry too quickly, flour paste may be added to the distempers to increase their working time.²⁷

1.4 Additional Types of Distemper

It should be noted that several of the 18th century treatises describe different types of distemper. The first is *common* (or *soft*) distemper referring to the basic recipes and applications that have already been discussed. This thesis will continue to focus on the common variety alone. However, there are two other types that are worth mentioning here. The procedure for *varnished distemper* or *chipolin* is outlined in the following seven steps: 1) application of one coat of size; 2) 7-10 layers of whiting + size; 3) smoothing and pumicing the surface until glossy; 4) recutting any sculptural (or three-dimensional decorative areas) to retain their crisp lines; 5) paint with tinted distempers; 6) apply a coating of size; 7) finish with a coating of varnish.²⁸ This technique would produce a very smooth, almost glossy surface, obviously very different than the matte sheen of common distemper. The fact that it is more labor intensive than other glossy alternatives, such as oil paint, suggests that it had a distinct and desirable appearance. In his 1785 treatise Watin extols the virtues of chipolin:

One can offer to the rich person more riches, more sumptuous embellishments, but one cannot present to the wise person more noble, more economical and more lasting decoration.²⁹

²⁷ Irish or Iceland moss (a type of seaweed) and glycerine are also recommended in *The Expert Calciminer* as an additive for prolonging working time. Kelly, 75.

²⁸ Adapted from Watin, 16-17.

²⁹ Watin, 9-16.

The other type of distemper to be noted is *Blanc de Roi* (*king's white* or *royal white*), as the king's apartments were often painted in this way. The procedure is similar to that for chipolin, except that the paint consisted of lead white combined with size, and there was no final application of varnish, so the surface remained matte. The content of lead in the paint film made this finish prone to blackening.³⁰ Blanc de Roi was often used in rooms with gilding, as the pure white, matte surface complemented the luminosity of the bright gold.³¹

³⁰ This was probably due to the chemical reaction between lead and atmospheric sulfur creating the black by-product lead sulfide.

³¹ Watin, 17

Chapter 2

Distemper and Polymer Dispersion Paint Films

The chapter describes the constituents of distemper and polymer dispersion paints, explaining the transition processes that take place as the liquid films become solid layers. Although both distemper and flat polymer dispersion paints are considered to be matte, water-soluble, and are used for similar purposes, the following sections examine the differences between the paint ingredients and mechanisms of film formation, and how these might contribute to the resulting optical and mechanical properties of the two paints. The physical characteristics of distemper determine which methods of modification will be most appropriate for enhancing its strength and durability without compromising its distinct optical qualities.

2.1 Film Formation and Anatomy

Paints (in their liquid form) are comprised of three major constituents: colorant, binder (or medium), solvent and/or diluent. The most prevalent type of colorants are pigments, insoluble

particles that impart color, hiding power, and texture to the resulting paint layer.³² Binder is the film-former, adhering the pigment particles to the substrate surface and to each other. Solvent keeps the binder in solution, or another workable state, so that paint can be applied to a given surface. Solvents are volatile components, eventually evaporating and leaving the pigment and binder in a solid film. Together the binder and solvent are often referred to as the 'vehicle'.

Distemper paint films contain gelatin (or hide glue) as the binder and water as the solvent. The film formation of these paints is categorized as a *solvent loss* mechanism, followed by cross-linking of the polymers to each other (primarily hydrogen bonding). While in solution, the gelatin molecules are dispersed by the water molecules. This occurs because the bonds between the water molecules and gelatin molecules are greater than or equal to the secondary bonds between the gelatin molecules to each other. As the water evaporates the dispersed long-chain gelatin polymers begin to settle out of solution. The long polymer chains (each one comprised of several similar molecules) become tightly compacted and intertwined due to solvent loss and intermolecular attraction and bonding, eventually resulting in a continuous film. The pigment particles are bound within the entangled polymers. The resulting paint film is a thin solid layer of gelatin containing interspersed pigment particles, with many extending beyond the top of the binder layer. The large amount of protruding particles creates a porous and textured surface that accounts for much of the distinctive matte appearance of distempers. Gelatin is a relatively strong binder; therefore, only a minimal amount is required to provide adequate cohesion (securing pigment particles together within the paint film) and adhesion (adhering the pigment

³² Additional colorants include: dyes - soluble colorants; and lakes - dyes that have been absorbed or precipitated onto insoluble particles.

particles to the substrate surface).

Modern (commercially available) polymer dispersion paints³³ have a more complicated system. The process of solidification is referred to as *film formation by coalescence*. The vehicle for polymer dispersion paints is in the form of a dispersion, as the name suggests, meaning a system comprised of a substance (semi-solid or solid) dispersed in an immiscible liquid³⁴. A Material Safety Data Sheet for a typical flat interior polymer dispersion paint indicates that the dispersion consists of vinyl-acrylic latex suspended in water³⁵, although a variety of synthetic polymer binders are commonly used. These paints are often described as ‘water-soluble’, however, the particles of acrylic polymer (usually spherical in shape) are not truly dissolved (separated into component parts) in the solution. Surfactants may be added to the dispersion to help maintain the suspension by keeping the particles of polymer from touching each other while in solution. As the volatile water evaporates, the polymer units merge to form a solid film. Coalescing agents (slow evaporating solvents) are often added to soften the polymer particles and encourage fusion. The pigment particles become entrapped within the solidified polymer. Since the acrylic polymer is not truly dissolved by water, the resulting paint film is relatively water resistant and washable.

³³ The terminology used for synthetic resin, water-based paints can be confusing. Polymer dispersion paints are commonly referred to as ‘dispersed polymer emulsion paints’, however the term *emulsion* specifically means a liquid suspended in an immiscible liquid. In the case of polymer dispersion paints, the polymer droplets are in a softened, but semi-solid state. Another common term for these paints is ‘latex’, which again is a specific term used for a particular category of synthetic resins.

³⁴ Webster’s Dictionary defines immiscible as “incapable of mixing or attaining homogeneity”. *Webster’s Seventh New Collegiate Dictionary* (Springfield: G. & C. Merriam Company, 1965), 417.

³⁵ MSDS submitted by Benjamin Moore & Co. for their Muresco® Ceiling White 258. See Appendix 8.1 for copy of the MSDS.

2.2 Pigment

Pigment particles impart a range of qualities used to enhance paint films: color, opacity, and hiding power³⁶. The particles also minimize shrinkage of the solidifying paint layer, much like sand particles in a mortar mixture. A variety of physical properties, including refractive index, pigment particle size, particle shape, orientation, and crowding, determine the optical and mechanical effects a given pigment will contribute to the paint layer.

Color imparted by the pigment particle is determined by its reflection or absorption of light. A paint film will appear white when the pigment particles scatter and reflect approximately 85 per cent of the light within the film. Pigment surfaces that absorb at least 90 per cent of the incident light will cause the paint film to appear black. All other colors are observed by the particles absorbing particular wavelengths of light and scattering the others - it is the reflected light frequencies that determine the color we perceive.

The predominant pigment in most architectural paint systems is white - the color of many of the extender pigments. Extender pigments, as the name implies, are inexpensive pigments used to increase the bulk of the paint, therefore reducing the amount needed of the more costly tinting pigments.³⁷ In addition, extender pigments may be used to impart specific mechanical or optical properties. One of the most widely used extender pigments is calcium carbonate, the major component in a distemper paint. The main white tinting pigment in a modern typical flat interior

³⁶ Hiding power generally refers to a paint film's ability to conceal the underlying substrate on which it is applied.

³⁷ Among the most common extender pigments currently used are: calcium carbonate, diatomaceous earth, kaolin, talc, baryte, mica, and aluminum silicate. Henry Ralston, "Extender Pigments," *Paint and Coating Testing Manual*, edited by Joseph V. Koleske (Philadelphia: ASTM, 1994), 220-1.

wall paint is titanium dioxide, often combined with fine-particle-size calcium carbonate as an extender.

White pigment particles are essentially translucent - most light that is not reflected is transmitted through the particle without being absorbed. Particle size also appears to affect the pigment's ability to appear opaque. H. E. Ashton notes that titanium dioxide particles provide optimum hiding power in a paint layer when they are 0.2 to 0.3 microns. The mineral can be a perfectly clear crystal when viewed in its larger form³⁸. Optimum particle size is directly related to the refractive index of the pigment. R. B. North states that:

Particle size and particle size distribution influence hiding power, viscosity, enamel holdout, oil (resin) demand, and gloss... As a general rule, all the characteristics mentioned increase as the particle size decreases; that is, fine particle size products are used when high gloss is a requirement, while coarser grades are the choice for a flat interior wall paint.³⁹

When a paint layer contains a large amount of small pigment particles, although they might be semi-transparent when viewed individually, the incident light is reflected and diffused in various directions from the particle surfaces. The collective result is the appearance of a white opaque paint layer - this phenomenon is called scattering. Morgan Phillips provides the example of snow to illustrate the concept of scattering.⁴⁰ Snowflakes are actually transparent crystals, but when a significant amount of flakes are collected together the pile appears to be white and opaque.

³⁸H. E. Ashton, "Paint - What Is It?," *Canadian Building Digest*, No. 76 (April 1966), 2.

³⁹R. B. North, "Natural Calcium Carbonate," *Pigment Handbook*, edited by Peter A. Lewis (New York: John Wiley & Sons, 1973), 93.

⁴⁰Phillips 1994a, 237.

The index of refraction also contributes to the optical performance of pigment particles within a paint layer. Robert Feller and Michael Bayard provide the following description of this optical characteristic:

When light passes from a less dense to a more dense medium, its velocity is slowed down; a beam of light will be bent or refracted. The ratio of the velocity of light in air (ideally, the velocity in a vacuum) to the velocity in various substances is expressed as the index of refraction or *refractive index*, [n] of the substance. It is measured by the angle at which the ray is bent, specifically; it is the ratio of the sine of the angle of incidence of the light ray to the angle of refraction...⁴¹

The index of refraction values for the pigment and binder should be significantly different from each other in order for the paint film to appear opaque, therefore providing hiding power. When the two are similar in value, light is transmitted through the paint layer, rather than being scattered or absorbed, resulting in a translucent film. Morgan Phillips again uses snow to illustrate the effect. In a pile of snow there is air surrounding the individual snowflakes. The index of refraction value for the ice crystals is significantly higher than that of the surrounding air spaces, and so the pile of snow appears to be opaque. However, as the snowflakes begin to melt, and water surrounds the crystals, the pile begins to appear translucent because there is a negligible difference in refractive index values between the remaining snowflakes and the adjacent water.

Extender pigments, such as calcium carbonate, usually have a low refractive index and so do not significantly contribute to hiding power in binder-rich semi-gloss and high-gloss paints. Extender pigments, however, can effectively (and inexpensively) contribute to the opacity of pigment-rich porous matte paint films such as distemper – the mechanism is explained in the following section.

⁴¹ Robert L. Feller and Michael Bayard, "Terminology and Procedures Used in the Systematic Examination of Pigment Particles with the Polarizing Microscope," *Artist's Pigments: A Handbook of Their History and Characteristics*, vol. 1, Robert Feller, ed. (New York: Oxford University Press, 1986), 289-90.

2.2.1 Pigment Volume Concentration

Pigment Volume Concentration (PVC) is an essential factor when examining the physical and optical properties of a paint film.

$$PVC = (\text{pigment volume}) \div (\text{pigment volume} + \text{binder volume})^{42}$$

The amount of binder present in the paint film directly affects the optical properties of the pigment. In matte paints such as distemper, the pigment volume is quite high. This means that the paint film is porous (there are voids between the pigment particles) which allows the light to diffuse as it is reflected by the multiple exposed surfaces of the pigment particles. In the case of distempers it also allows calcium carbonate (whiting) to provide good hiding power. This pigment has a relatively low index of refraction ($n = 1.6$), the value being close to most organic binders ($n = \sim 1.5$). When used in high PVC paints, the calcium carbonate particles on the surface of the paint film are surrounded by air which has a significantly lower index of refraction ($n = 1$), therefore the particles appear opaque. The mechanism of light scattering at pigment/air interfaces is known as 'dry hiding'.

Robert L. Feller and Noel Kunz carried out a series of experiments examining the optical effects of pigment volume concentration on matte paints. They showed that maintaining a high pigment to volume concentration is essential when consolidating porous paint surfaces; if the percentage of consolidant is increased significantly, eliminating the air in the interstices, the paint film becomes dark or transparent. Darkening occurred even when binders having low indexes of refraction were

⁴² Eric F. Hansen *et al*, *Matte Paint: Its History and Technology, Analysis, Properties and Conservation Treatment* (Getty Conservation Institute, 1994), xxxvi.

used (Ultramarine blue was selected as the pigment for the experiments because of its low index of refraction, approximately 1.5).⁴³

There is an optimum range for the pigment volume concentration of a given paint film known as the *Critical Pigment Volume Concentration*. This concept is described by Walter K. Asbeck in "A Critical Look at CPVC Performance and Application Properties":

The Critical Pigment Volume Concentration (CPVC) of a coatings system is a ubiquitous property which directly or indirectly affects the manufacture, application, performance and appearance of all solution resin or latex type coatings. It is the transition point above or below which substantial differences in behavior of a paint film will be encountered. The CPVC is that point at which just enough binder is present to fill completely the voids left between the pigment particles in the film after volatilization of all thinner and represents the degree of most dense packing of the pigment particles commensurate with the degree of dispersion of the system.⁴⁴

The CPVC is determined by the properties of both the pigment and binder. Asbeck notes that the CPVC for the same pigment can be distinctly different when added to various binders having different dispersive capacities.⁴⁵ Juergen H. Braun states that 'fluffy' or loosely packing particles have a low CPVC, while particles that pack densely (and are more well-dispersed) have a high CPVC.⁴⁶ Calcium carbonate pigments generally fall into the latter category and so are often used as the primary pigment in high CPVC matte paints such as distemper.

⁴³ Robert L. Feller and Noel Kunz, "The Effect of Pigment Volume Concentration on the Lightness or Darkness of Porous Paint," *Preprints of Papers Presented at the AIC Ninth Annual Meeting, Philadelphia, PA; May 27-31, 1981*: 66-74.

⁴⁴ Walter K. Asbeck, "A Critical Look at CPVC Performance and Application Properties," *Polymeric Materials Science and Engineering: Proceedings of the ACS Division of Polymeric Materials*, vol. 63 (Fall 1990), 1.

⁴⁵ *Ibid.*

⁴⁶ Braun defines packing density as "...[the] inverse measure of interstitial volume, a reflection of the way pigment particles aggregate and agglomerate into either stringy assemblies that haystack or compact clumps that pack densely." Juergen H. Braun, "White Pigments," *Paint and Coating Testing Manual*, edited by Joseph V. Koleske (Philadelphia: ASTM, 1995), 168.

2.3 Gelatin / Glue

As previously mentioned, the binding component of a distemper paint is animal glue, or gelatin (animal glue in its refined, or purified, form)⁴⁷. The primary constituent of gelatin is collagen, an insoluble fibrous protein. Collagen is found in the skin (or hide), bones, and connective tissue of vertebrates. Traditionally, glue was obtained by the prolonged heating of animal hide and bones in water; however, glues derived from animal hides are generally higher in molecular weight and strength than those derived from animal bones.⁴⁸

Animal glue was one of the strongest and most commonly used adhesives throughout history, and has only been recently superseded by the development of synthetic resins. For this reason, much of the scientific literature about animal glues and gelatins was published in the 19th and early 20th centuries. The present use of animal glues and gelatin is limited to the food industry, photographic industry (as a dispersing medium for the light-sensitive silver halide particles in a photographic emulsion), occasional use in artist's materials, and in the field of fine arts conservation (predominantly as an adhesive for furniture and wooden artifacts, and more rarely as a consolidant).

Collagen is a protein comprised of interconnected amino acids. The successive linking of the amino acid molecules form a network polymer (a continuous chain of molecules consisting of a two or three-dimensional network). The formation process is called addition polymerization, as

⁴⁷ Although animal glues are predominantly gelatin, they may contain additional proteins such as; keratin, elastin, mucin, and chondrin. Rutherford J. Gettens and George L. Stout, *Painting Materials: A Short Encyclopedia*, 2nd ed. (New York: Dover, 1966), 25.

⁴⁸ C. V. Horie, *Materials for Conservation: Organic Consolidants, Adhesives, and Coatings* (Oxford: Butterworth-Heinemann Ltd., 1987), 142-3.

there are no by-products. The molecules become permanently bound together at certain points along the molecule chain, which is called cross-linking. In the case of gelatin, the collagen molecules are connected to each other by multiple hydrogen bonds, and occasional covalent bonds.⁴⁹

Gelatin is an emulsoid, a colloidal system where a liquid is dispersed in a liquid. Gelatin molecules are partially hydrolyzed in water – secondary bonds between the gelatin molecules are broken and replaced by new bonds formed with elements of the water molecules (primarily hydrogen). Gelatin is considered a ‘solvent loss’ adhesive. As the solvent (water) evaporates the long chain molecules become intertwined with each other, in addition; the side groups form hydrogen bonds and covalent bonds which cross-link the molecules. The volume of this class of adhesives becomes significantly smaller as the solvent is lost. The resulting gelatin film is relatively insoluble in the presence of most common solvents; however, it is prone to softening and swelling when exposed to moisture. Sufficient water and heat are required to completely resolubilize the gelatin. Gelatin will return to its original state upon drying, although if the atmospheric moisture drops too low the gelatin (or glue) will shrink and become brittle compromising its adhesive properties. Birstein and Tul’chinsky demonstrated that gelatin becomes insoluble when the amount of moisture is less than 1%. (moisture loss being a common characteristic of an aged film), a phenomenon they attribute to an increase in intermolecular bonds.⁵⁰ It should also be noted that gelatin/glue will lose some of its strength upon subsequent reheating.

⁴⁹ Ibid, 142.

⁵⁰ V.J. Bierstein and V.M. Tul’chinsky, “IR-Spectroscopic Analysis of Aged Gelatins”, *ICOM Committee for Conservation*, 6th Triennial Meeting, Ottawa 1981, 81.1.9-6.

Gettens and Stout describe gelatin's physical characteristics:

"It is a nearly colorless, transparent, amorphous substance. In its normal, dry state, in which it still retains 15 to 18 per cent water, it is flexible and horny, and has a slight yellow cast...[T]he viscosity of its solutions is high and variable with slight alterations in temperature, concentration, hydrogen-ion concentration, etc. It swells to many times its normal volume when immersed in cold water or in dilute acids or alkalis; a slightly acid solution is the most favorable for maximum swelling. Above 35° C., the swollen jelly goes readily into solution. A firm jelly is formed when a solution containing 1 or more per cent of gelatin is allowed to stand at 10° C."⁵¹

Gelatin's primary weakness as an adhesive is its propensity to shrink and swell when subjected to changes in atmospheric moisture. The constant internal stresses caused by the dimensional changes continually compromise the integrity of the film and its adhesive properties. The effects of humidity on collagen (the primary component of gelatin) are clearly demonstrated in the experiments carried out by M. F. Mecklenburg.⁵² A variety of substances have been added to gelatin solutions throughout history to enhance water resistance of the resulting films. An overview of these additives will be reviewed in the following chapter. Since gelatins and animal glues are also prone to attack by moulds and fungi, various biocides have been added to these adhesives to inhibit biological growth.

⁵¹ Gettens, 25.

⁵² M. F. Mecklenburg, "The effects of Atmospheric Moisture on the Mechanical Properties of Collagen Under Equilibrium Conditions," *Preprints of Papers Presented at the 16th Annual Meeting, New Orleans, Louisiana, June 1-5, 1988* (Washington D.C: AIC, 1988), 231-44.

Chapter 3

Experimental Design and Laboratory Testing Program

3.1 Survey of Additives for Enhancing Mechanical Properties

The previous section discussed the physical properties and characteristics of gelatin films, including its propensity for absorbing atmospheric moisture. Gelatin can swell significantly in the presence of high humidity, then shrink substantially as the humidity decreases and the water is lost. The continual expansion and contraction exerts significant stresses and strains on the film, potentially causing it to fail. Since gelatin and animal glues are often used in environments where the atmospheric moisture cannot be controlled, there is a history of incorporating various additives to the adhesive solutions in an effort to minimize the effects of moisture. Although the experimental program of this thesis limits the modification of the distemper to a single additive, a review of both the traditional and modern materials used may prove to be useful for future research and testing. These additives have been used in several contexts; primarily industry, architectural paint formulas, and the conservation of matte paints.

Industry

The following chemicals are recommended as additives for enhancing the water resistance of gelatins and animal glues: formaldehyde, hexamethylenetetramine, aluminum sulfate, and sodium bicarbonate.⁵³ Braude discusses two methods for incorporating an insolubilizing agent:

In practice, there are two ways of making a glue insoluble. The less desirable procedure is to apply the glue to the wood and before the glue is dry to apply the insolubilizing solution on it. The surfaces to be joined are then set together. In the preferred method, the insolubilizing substance is mixed with the glue under such conditions that no reaction occurs until the glue is applied. Formaldehyde is most frequently used for this purpose, about 1% on the weight of dry glue. Together with the formaldehyde, one must use some substance to slow up its reaction with gelatin. Ammonium sulfocyanide, acetic acid and ammonium hydroxide are used for this purpose. The acetic acid and ammonium hydroxide evaporate as the glue dries which enables the formaldehyde to act. A similar situation exists when alum is used with acetic acid. One of the best ways of making waterproof glue is to use hexamethylene-tetramine. This compound gives off formaldehyde when warmed gently.⁵⁴

A variety of gelatin ‘hardeners’ are reviewed in *The Theory of the Photographic Process*, including explanations of how the additives chemically alter the gelatin. The chemicals are categorized as inorganic or organic. The primary inorganic hardeners are chromium and aluminum salts, and the potassium and ammonium alums. The organic group includes: aldehydes, n-methylol compounds and other blocked aldehyde hardeners, ketones, carboxylic and carbonic acid derivatives, sulfonate esters and sulfonyl halides, active halogen compounds, epoxides, aziridines, active olefins, isocyanates, carbodiimides, and hardeners of mixed function (a “combination of two or more different active hardening functions in the same molecule”).⁵⁵ It should be kept in mind that these additives may have specific applications that are limited to photography and their effects may not be appropriate in other contexts.

⁵³ Felix Braude, *Adhesives* (Brooklyn: Chemical Publishing Co., 1943), 75.

⁵⁴ *Ibid*, 75-6.

⁵⁵ J. Pouradier and D. M. Burness, “The Hardening of Gelatins and Emulsions,” *The Theory of the Photographic Process*, by T. H. James, 4th ed. (New York: Macmillan, 1977), 54-9.

An article published in *Chemical and Metallurgical Engineering* discusses the results of a study that examined the effects of additives on the viscosity and 'jell' strength of glues and gelatines.⁵⁶ Among the additives tested were: formaldehyde; methyl, ethyl, and amyl alcohols; aluminum, chromium and iron potassium alums. The acids, bases, and salts tested all decreased the jell strength, and do not warrant further evaluation for architectural paints.⁵⁷

Architectural Paint Formulas

In *The Expert Calciminer* A. Ashmun Kelly provides several variations on the basic calcimine (or distemper) recipe - modified to enhance its physical properties. In one formula for an 'Alkali-Proof Liquid for Mixing Calcimine', he states that the recipe produces a paint that will:

... adhere to almost any surface, doing well on stone, brick, tile, wood, plaster, mortar, glass and metal, alike on surfaces rough or smooth. And exposure to the weather does not impair the colors. The surface coated with this paint will bear washing and scrubbing, after it has become hard. The borax causes the mixture to harden upon exposure to the air. It may be used for fresco work on interior and exterior walls. It is proof against atmospheric influences, and may be varnished over, when it will be fully as durable as oil paint of the best grade.⁵⁸

This alkali-proof paint is basically a distemper (calcimine) thinned with a mixture of gum Arabic (gum acacia) and borax (hydrated sodium borate) diluted in water. To one quart of the gum Arabic solution (gum Arabic thinned with water to the consistency of honey) add one ounce of powdered borax, producing a thick brittle jelly. The mixture is then thinned with additional hot

⁵⁶ Robert H. Bogue, "Properties and Constitution of Glues and Gelatines - I: A Study of Factors Influencing Viscosity and Jell Strength - Effect of Time, Mechanical Treatment, Heating and Dehydration - Influence of Concentration, Temperature and Added Substances," *Chemical and Metallurgical Engineering*, vol. 23, no.1, July 7, 1920: 5-11.

⁵⁷ Ibid, 5-11

⁵⁸ Kelly, 62-3.

water to an appropriate consistency to thin the distemper. Kelly does not provide relative proportions of the thinning agent to the distemper.⁵⁹

Kelly refers to an alternative distemper recipe (provided by a contemporary decorator), in which alum (an aluminum sulfate, most commonly a potassium aluminum sulfate) is added to the glue binder prior to mixing it with the calcium carbonate/pigment. (1/2 lb. or pulverized alum: 1 lb. of white glue: 16 lb. whiting).⁶⁰ The alum hardens the resulting gelatin film, rendering it more water resistant.

Under Kelly's recipes for 'Damp-Proof Calcimine' he recommends using one of the following ingredients: sodium phosphate, chrome alum, or formalin, any of which will enhance the water resistance of the paint films when incorporated into the basic distemper formula. In most cases it is recommended that the additive be mixed in with the warm glue solution.⁶¹ Additional recipes include an 'Oil-Water Calcimine', which uses sal or washing soda (hydrated sodium carbonate decahydrate) and linseed oil mixed with the glue solution, and a 'Flat Washable Water Paint'. Kelly provides three formulas for the latter paint, each containing the calcium carbonate pigment base. The following is a list of the three vehicle (binder+solvent) variations: 1) soda or borax mixed with white shellac, glycerine, and denatured alcohol – adding raw linseed oil and turpentine as necessary to adjust the consistency (there is no glue in this recipe); 2) The second is similar to the first but with the addition of boiled linseed oil. Kelly notes that this formula produces a higher

⁵⁹ Ibid, 62.

⁶⁰ Ibid, 65.

⁶¹ Ibid, 66.

gloss paint; 3) In addition to the calcium carbonate/pigment, the final formula includes; white lead in oil, raw linseed oil, brown soap (melted), and copal varnish.⁶²

The final distemper recipe variation recommended by Kelly substitutes a gelatin derived from seaweed (Irish moss or Iceland moss, possibly having the Latin name *Chandrus*) instead of the animal product. He notes the superior working properties of distemper made with the seaweed gelatin, especially when working in warm weather – as it increases the working time. Kelly suggests using the following ingredients for this recipe: seaweed gelatin, boric acid (as a biocide, this may be substituted with another appropriate ‘anticeptic’), and calcium carbonate.⁶³

Materials Used in the Conservation of Matte Paints

An article by Elizabeth Welsh summarizes her literature review on consolidation treatments carried out on matte paints in the conservation field.⁶⁴ The following is a list of the products found in her survey: poly n-butyl methacrylate, soluble nylon (N-methoxymethyl nylon), cellulose ethers (methyl cellulose, hydroxyethyl cellulose, sodium carboxymethyl cellulose, etc.), polyvinyl alcohols, polyvinyl butyral, polyvinyl acetate, Elvacite 2013 (a methyl/n-butyl methacrylate copolymer), poly methyl methacrylate, and Acryloid B-72 (an ethyl methacrylate/methyl acrylate copolymer). Welsh concluded that Acryloid B-72 was the most suitable consolidant, based on its chemical stability (including resistance to cross-linking), resistance to yellowing over time, and physical properties (such as flexibility). An additional advantage is that it has been studied for over 35 years, and so its behavior upon aging can be predicted. Welsh developed a consolidation method using diethylbenzene as the solvent. The fact that many of the products listed above are

⁶² Ibid, 66-7.

⁶³ Ibid, 75-6.

not water-soluble may render them impractical as additives in a water-based distemper paint formula.

Morgan Phillips also carried out research into various techniques used to consolidate matte paints: his summary includes materials that range from the traditional (water, gelatin, starches, vegetable gums) to modern synthetic products (cellulose ethers, solvent-soluble resins, synthetic resin emulsions, cross-linking agents, ethyl silicates).⁶⁵ Phillips discusses the consolidation process, and advantages and disadvantages for each category of consolidant. These product evaluations are particularly useful since Phillips factors in their appropriateness in an architectural context.

In his case study, the paint reattachment and consolidation of a distemper trompe l'oeil ceiling, Phillips outlined two procedures that were employed. 1) In one of the initial test areas he somewhat successfully used a high quality gelatin (Silver Label) which he applied by brush to the damaged areas. He found that the addition of a wetting agent was very useful in aiding the quick migration of the gelatin. Although Phillips found adhesion of paint in this test area was already beginning to fail after two years, he felt that with minor adjustments in the strength of the gelatin and application procedure that the method had potential for future projects. The consolidant he selected for the actual treatment was a 4 per cent solution of Acryloid B-72 (Rohm & Haas) in toluene, which was sprayed on to the surface.

In "Injection Grouting of Mural Paintings and Mosaics" Ferragni, *et al.* state that diluted synthetic resin emulsions have been successfully used in the field as an adhesive and gap filler for the

⁶⁴ Elizabeth Welsh, "A Consolidation Treatment for Powdery Matte Paint," *Preprints of Papers Presented at the 8th Annual Meeting, San Francisco, California, May 22-5* (Washington D.C: AIC, 1980), 141-8.

⁶⁵ Phillips 1994b, 154-69.

reattachment of wall murals and mosaics to their substrate.⁶⁶ However, they note that these emulsions are most appropriate for filling small or narrow gaps, and should bear only a small load. They also incorporated a synthetic resin emulsion into their various hydraulic lime-based grouting mixtures to initially reduce the amount of water lost (therefore decreasing the viscosity of the grout) and to provide initial tackiness. The commercial product used for their formulations was Primal AC-33 (also known as Rhoplex AC-33, and Rhodoplex).⁶⁷

3.2 Modified Distemper Formulations

The decision was made to limit the modified recipes to a single additive, since the focus of this study was to establish an effective experimental program for evaluating the performance of these paints, and what effect, if any, the relative quantities of an additive imparted. Limiting the number of variables was critical to evaluate the experimental results. Seven different paint formulations were selected for comparison and evaluation; a traditional distemper, four modified distemper recipes, a synthetic distemper, and a commercial synthetic polymer dispersion flat paint. The basic distemper recipe was made with a 14% solution of gelatin (% solids by weight).⁶⁸ One part of the gelatin solution was mixed with two parts of calcium carbonate (artist grade⁶⁹) soaked in water; the 1:2 portions were measured by volume. A large enough quantity of the traditional distemper was made so that all of the modified recipes could begin with the same base, eliminating one potential variation between the formulas. Rhoplex AC-33 (discussed in the following section) was added to the basic recipe in varying amounts to create mixes that contained 2%, 5%, 10%, and

⁶⁶ D. Ferragni, *et al.*, "Injection Grouting of Mural Paintings and Mosaics," *Adhesives and Consolidants: Preprints of the Contributions to the Paris Congress, 2-8 September 1984*, edited by N.S. Brommelle *et al.* (London: IIC, 1984), 110.

⁶⁷ *Ibid.*, 112.

⁶⁸ This is the same basic recipe employed by Cassie Myers at Market Hall

⁶⁹ The gelatin (in sheet form) and calcium carbonate (chalk/whiting from Champagne, France) were both purchased from Kremer Pigments, Inc.

20% AC-33 by volume. An additional synthetic distemper formula was made using 2 parts whiting soaked in water (without gelatin), added to 1 part Rhoplex AC-33 that had been diluted to a 14% solution of solids by weight. (This recipe was created so that a direct comparison could be made to the traditional distemper – both formulas contained 14% of the respective binder by weight.)

The final paint evaluated was Benjamin Moore's *Muresco® Ceiling White*, a flat interior polymer dispersion paint. A commercial paint was included in the experiments to serve as a standard point of comparison, since it is essentially the modern equivalent of distemper in both general appearance and use. Ceiling paints are among the flattest paints on the market, and so most closely approximate a traditional distemper.⁷⁰ According to the product information sheet, the Muresco® paint is comprised of a vinyl-acrylic binder thinned with water. The liquid paint is 29% solids by volume. (*See MSDS and product information sheet in Appendix 8.1*) This particular polymer is associated with reasonable scrub-resistance – a physical property that is considered to be one of the highest consumer priorities.⁷¹ Vinyl-acrylic paint films are formed by solvent loss and subsequent coalescence of the polymer spheres, as described in section 2.1.

The seven paint formulas were applied to a variety of substrates, as determined by the experimental requirements. In addition, several methods of application were employed - using both brushes and film applicators. These are described in Chapter 3.

⁷⁰ There are commercially available 'distemper' and 'calimine' paints available from decorative and historic paint companies, many of which are said to have enhanced durability. Although these were not included as part of this study, it is recommended that they be evaluated in future research.

⁷¹ Joseph V. Koleske, ed., *Paint and Coating Testing Manual* (Philadelphia: ASTM, 1995), 47.

It should also be noted that none of the formulations contained any tinting pigments or biocides, since these could potentially effect the optical and physical properties. The need for a preservative/biocide was eliminated by evaluating samples within two months of the sample preparation. In addition, none of the physical tests involved water or artificially increased humidity in the environment. If water-related tests are carried out in the future, it is recommended that biocides be present in the formulations.

3.2.1 Acrylic Emulsion Rhoplex AC-33: Properties

Rhoplex AC-33 (also known as Rhodoplex and Primal AC-33) is an acrylic polymer dispersion produced by Rohm & Haas Company. The ingredients listed on the MSDS⁷² (*see Appendix 8.1*) are: acrylic polymer (45-48% by weight), individual residual monomers (<0.1%), aqua ammonia (0.2% max.), and water (52-55%). The term 'acrylic' is the common name used for polymers relating to acrylic acid (an unsaturated liquid acid) or its derivatives. The systemic name for acrylic acid is propenoic acid, indicating that the longest continuous polymer chain is comprised of three carbons⁷³. Propenoic acid, a carboxylic acid, is relatively soluble in water, where intermolecular forces between the molecules are replaced by hydrogen bonds in an aqueous solution.⁷⁴ Although the MSDS does not specify the exact composition of the acrylic resin in Rhoplex AC-33, analysis by Howells *et al.*, revealed that the mixture is comprised of the following acrylic acid derivatives: 60% ethyl acrylate (EA); 40% methyl methacrylate (MMA); and possibly a small percentage of ethyl methacrylate.⁷⁵ Horie states that the P(MMA/EA)

⁷² It should be noted that an MSDS does not list all of the ingredients present in the referenced product. A manufacturer is only required to include components that are potentially toxic or hazardous

⁷³ The systemic name for a three-carbon unbranched alkane is *propane*.

⁷⁴ Francis A. Carey, *Organic Chemistry* (New York: McGraw-Hill, 1987), 736.

⁷⁵ R. Howells *et al.*, "Polymer Dispersions Artificially Aged," *Adhesives and Consolidants: Preprints of the Contributions to the Paris Congress, 2-8 September, 1984* (IIC, 1984), 37.

polymers in this product are actually co-polymers⁷⁶, meaning that a single Rhoplex AC-33 acrylic polymer contains both MMA and EA molecules.

Rhoplex AC-33, like most acrylic dispersions, initially forms a film upon evaporation of the solvent, followed by coalescence of the acrylic particles. (*See section 2.1*). According to Horie, Rhoplex AC-33 forms a relatively stable film and is one of the more “reliably soluble” acrylic adhesives, although he notes that the properties of synthetic resins tend to vary between batches.⁷⁷ Rhoplex’s chemical stability and potential reversibility make it a suitable product for a variety of conservation purposes.

The glass transition temperature (T_g) for Rhoplex AC-33 is 16° C (61° F), slightly below room temperature. When polymers are in an environment at or above their T_g the molecules can move and flow to accommodate stresses, however, if the atmospheric temperature is too high the polymer film may remain soft and prone to collecting particulate along the surface - and in some cases may never set properly. When polymers are subjected to temperatures significantly below their T_g , the molecules are frozen in place and brittle. Therefore, adhesives and consolidants used in conservation normally have a T_g around room temperature. In contrast, gelatin has a T_g of 210° C (410° F), but because of its propensity for absorbing atmospheric moisture, it may become soft at room temperature in higher humidities.⁷⁸

⁷⁶ Horie, 110.

⁷⁷ Ibid, 112.

⁷⁸ Ibid, 123.

It is estimated that the refractive index (n) for Rhoplex AC-33 as a dried film is $1.47 \pm .01$.⁷⁹ Most organic binders, including gelatin, have a refractive index around 1.5. The refractive index compatibility with gelatin and calcium carbonate ($n=1.6$), makes Rhoplex AC-33 an appropriate additive.⁸⁰ Other factors that should be considered in future tests, where a variety of additives are to be evaluated, are their miscibility, hydrophobicity/hydrophilicity of the solidified polymer, and potential secondary bonding with the gelatin molecules.

The decision to use Rhoplex AC-33 as the primary additive for the distemper formulations was based on recent fieldwork carried out by Cassie Myers. Myers, an Architectural Conservator, tested several modified distemper recipes for the replication of distemper wall and ceiling finishes at Market Hall, located in Charleston, South Carolina. The extremely high humidity in Charleston could potentially cause accelerated failure of the gelatin-based distemper, which is prone to extreme dimensional changes in environments with humidity fluctuations. In an effort to provide a more practical and durable paint finish, Myers created and tested a variety of modified distempers. The most successful recipe tested in the field was modified with the addition of Rhoplex AC-33, 2% mixture by volume. Among the other recipes tested were 1% and 5% Rhoplex solutions; however, the 2% formula appeared to be the most successful in terms of enhanced durability (according to adhesion tests carried out on-site), and with minimal or no change in perceived appearance.⁸¹

⁷⁹ Michael T. Bender, PhD, Research Scientist at Rohm & Haas, private communication.

⁸⁰ Rohm and Haas discontinued production of Rhoplex AC-33 in March 2000, however, it can still be purchased from several art and conservation product suppliers. Rohm and Haas recommends a mixture of Rhoplex B60-A and Acrysol G-111 or Acrysol 60-38A as a substitute. Relative proportions of the two components were not given.

⁸¹ Cassie Myers, Conservator of Wall Paintings and Architectural Materials, private conversation.

3.3 Evaluation of Optical Properties

The following appearance characteristics were evaluated for the different paint formulations: gloss (the amount of *specular*, mirror-like, reflected light off a given surface), opacity (the capacity of a coating to obscure the underlying substrate), and relative hiding power. Gloss (specular reflectance measurements) and opacity (contrast ratio measurements) are both objective measurements whose values are determined using standardized instruments. The purpose of the gloss and opacity tests was to determine whether or not there are measurable differences in these optical properties between the various paint formulas, and if so, to gain insight about contributing factors (pigment to volume concentration; type of binder; type of pigment). In addition, notable differences between the modified formulas might suggest optimal parameters for incorporating additives into a formula without compromising the optical properties. The relative hiding power / leveling characteristics were evaluated subjectively (visually with the unaided eye) by making relative comparisons between surface appearances of the different samples.

Sample Preparation

Two sets of samples were prepared for the gloss and opacity measurements since these tests are non-destructive the same samples could be used for both tests. All seven paint formulations were applied to Leneta opacity charts (type 2A) 5.5" X 10". *(See Table 7.1 for a summary of the various sample preparation materials.)* The preparation surface of each chart is divided in half, where one portion is black and the other white. The background colors and the clear coating on the cards are standardized, and meet the requirements for ASTM (American Society for the Testing of Materials) tests. Each card was taped down onto a sheet of glass to ensure that the surface was level. A square multiple clearance applicator was placed near the top of the card and several milliliters of paint were deposited in the well. For the first set of samples, the applicator was

positioned on the chart so that the paint films were drawn down in a uniform thickness using the 6 mil (1 mil = 1/1000 inch) clearance bar - (at a width of approximately 2") across both the white and black portions of the chart. A second set was carried out in the same manner, but with the applicator positioned to use the 3 mil clearance bar. The actual wet film thickness is approximately half of the clearance measurement (e.g. a 3 mil clearance bar draws down a wet film of approximately 1.5 mil), and the resulting dry film thickness of a typical flat paint ranges from about one third to one half the wet film thickness (1.5 mil wet film would be approximately 0.5-0.75 mil upon drying). The set of samples drawn down with the 6 mil applicator produced a more consistently uniform film, and so the gloss measurements were carried out on this set alone.

Potential systemic errors lie in the sample preparation. All of the distemper formulations were mixed by hand and so there is the possibility that the pigment did not remain evenly dispersed. Draw-down bars were used in an effort to achieve paint films of uniform thickness, however, fluctuations in the rate at which the bars are drawn may cause slight variations in film thickness. Both of these factors could affect the film thickness, which as the opacity results reveal, directly impacts the contrast ratio.

The set of brushhous samples were applied on Leneta display charts (type 8A) 5.5" X 10". The test area on the charts is covered with a pattern of black and white diagonal stripes. The bold graphic background is designed to emphasize variations in the leveling and opacity of applied paint layers.

The method of application was adapted from ASTM Standard Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushhous (Designation: D 344 – 89). The following

procedure was carried out for each formula, two samples were brushed out for each recipe. The brush to be used was preconditioned by dipping it in the paint and brushing it out onto a surface. (The same 2" synthetic bristled brush was used for all of the samples. It was rinsed and shaken out prior to each use.) The preconditioned brush and a syringe containing 3 ml of the sample paint formula were placed into an empty beaker and weighed. The 3ml of paint was then distributed over the test area on the Leneta chart (which had been taped down to a sheet of glass – to both fix it in place, and to provide a level surface). The preconditioned brush was used to brush out the paint over the entire test area. The paint was first brushed over the surface in one direction, then subsequently brushed in the perpendicular direction. The paintbrush and syringe were weighed again in the beaker. The difference in weight was recorded.

Prior to carrying out the brushouts, the density of each paint formula was roughly measured. This was done by injecting 30 ml of the paint formula into a tared weighing dish. The paint was injected 10 ml at a time, recording the weight at each interval. The densities were calculated and the mean values recorded in Table 7.4. The amount of paint applied to the surface was calculated by converting the measured weight to ml using the known density.

$$\text{Volume (ml)} = \text{Weight (g)} \div \text{Density (g/ml)}$$

The volume of the paint sample applied to the card was then used to calculate the actual spreading rate⁸². (See Table 7.5)

$$SR_A = (B/A) \times SR_B$$

where:

SR_A = actual spreading rate

B = intended weight

A = actual weight, and

⁸² The term 'rate' typically refers to a change in some measure (such as distance, or weight, etc.) relative to time, however, in this ASTM test rate is used to describe the area covered during the paint application process relative to the volume of paint used.

SR_B = intended spreading rate

$$SR_B \text{ (for both sets of samples)} = 2.75 \text{ m}^2 \cdot 0.003 \text{ L} = 916.67 \text{ m}^2 \text{ L}$$

The viscosity (resistance to flow) of the distemper formulas can dramatically fluctuate depending on the temperature of the solution and the environment. The paints are very thin when warm, but eventually become semi-solid (gelatinous) as they completely cool. There is a window of optimal viscosity between those two extremes, where the paint settles to a reasonable thickness and levels well. Any inconsistencies in the viscosity of the applied paint samples could directly effect the two characteristics that were evaluated. If the paint was applied while it was too warm and thin, the resulting dry film thickness was inadequate and more transparent. Conversely, if the distemper was applied in state that was too thick, the paint would not level satisfactorily, resulting in a streaky and uneven appearance. Attempts were made to apply the various distemper formulas in a state of comparable viscosity.

3.3.1 Gloss (Specular Reflectance Measurement)

In *Matte Paint* 'gloss' is defined as:

[A] subjective term used to describe the relative amount and nature of mirror-like (specular) reflection. Different types of gloss are frequently arbitrarily differentiated, such as sheen, distinctness-of-image gloss, etc. Trade practice recognizes the following stages in increasing order of gloss: Flat (or matte) – practically free from sheen, even when viewed from oblique angles (usually less than 15 on 85~ [gloss]meter); Eggshell – usually 20-35 on 60~ meter; Semigloss – usually 35-70 on 60~ meter; Full gloss – smooth and almost mirrorlike surface when viewed from all angles, usually above 70 on 60~ meter.⁸³

⁸³ Hansen *et al.*, 527-8.

When evaluating gloss our eyes focus on how a light source is reflected on a given surface. One has the impression of high gloss when the light source appears to be directly reflected – the reflected light is comparably brilliant and the edges of the reflected image are distinct. With high gloss surfaces, most of the light is reflected at an angle equal to the angle of incident light. Conversely, matte or flat surfaces are perceived when the light source reflection is dull and indistinct, due to the diffuse scattering of the incident light (reflecting off the surface at multiple angles).

Gloss is visually evaluated as the combined perception of several surface properties; material, surface topography, degree of transparency, and substrate. An observer's perception is also influenced by the light source, and the individual's particular physiological and psychological state.⁸⁴ The human eye is particularly sensitive to subtle variations in gloss; however, perceptions can vary greatly from person to person. Kigle-Boeckler states that "Gloss is a subjective impression and not a physical property of the surface."⁸⁵

Although the total gloss impression may be subjective, a universally standardized method was developed to measure the relative surface appearance of coatings and materials. A glossmeter was designed to specifically measure the *specular reflection*⁸⁶ of a surface – a standardized value, and so, an objective component of the gloss impression. Kigle-Boeckler continues:

In order to obtain comparable results, the measurement device and operation have been defined in international specifications: ISO 2813, ASTM D 523, J ISZ874, and DIN 67530. The specifications define the following parameters: geometric conditions (angle of illumination and reflection, aperture angle, light

⁸⁴ Gabriele Kigle-Boeckler, "Measurement of Gloss and Reflection Properties of Surfaces," *Metal Finishing*, vol. 93: 28.

⁸⁵ Ibid, 29.

⁸⁶ Hansen *et al.* define 'specular gloss' as "the degree to which a surface simulates a mirror in its capacity to reflect incident light." *Matte Paint*, 533.

source, and detector sensitivity); calibration procedure; and application and limitations (e.g., curved surfaces).⁸⁷

Glossmeters contain an illumination source and a detector, which are both limited by an aperture. The light source and detector are directed toward the surface to be measured at a specified angle, typically 20° (for high-gloss paints), 60° (semi-gloss), and 85° (matte) - referring to the angle as measured from a line perpendicular to the surface. The intensity of the reflected light is measured by a photoelectronic detector as it passes through the detector aperture. The gloss measurement is a relative value. The surface measurement is compared to a black glass standard with a defined refractive index of 1.567 and an assigned specular gloss value of 100.⁸⁸ Each instrument is calibrated to a black glass standard that meets these specifications.

The angle of illumination has a direct effect on the amount of reflected light. The three geometries described above were created to differentiate between surfaces within a given category of gloss level. A chart in the 2001 BYK-Gardner Catalog illustrates the need for this differentiation.⁸⁹ In this graph surface finishes were categorized into three different perceived gloss levels, then measured using each of the three geometries. The slope of the curve varies significantly for each group of samples as the measurements are plotted for the different geometries. There is a clear point where the measured gloss values no longer correlate with the visual perception.

⁸⁷ Kigle-Boeckler, 30.

⁸⁸ Ibid.

⁸⁹ This chart was reproduced from *The 2001 BYK Gardner Instruments Catalog*, 14. (Byk Gardner USA is based in Columbia, Maryland.)

Testing Procedure

A Minolta Multi-Gloss 268 hand held gloss meter was used to carry out the measurements.⁹⁰ The glossmeter was calibrated to the black glass standard prior to taking measurements; all were taken in a single session. The 85° geometry was selected to provide the optimal angle for differentiating the results of matte paints. Ten measurements were taken from both the black and white portions of each sample card, and the results were plotted separately on a chart. The glossmeter was repositioned prior to each reading, so that measurements sampled the full surface of the paint film.

Results

The gloss measurements for all of the samples were very similar, falling into a narrow range of 2.5-3.5 gloss units (mean value). *(See Figure 6.1)* The standard deviation for the sample paint formulas was $\leq .56$. The gloss values are very low, raising the possibility that they are at the limit of the instrument's detectors. In an effort to validate the results, two pieces of matte fabric were also tested: 1) black melton wool, and 2) white cotton percale. The results were 0.1 and 0.5 respectively, indicating that measurements for the paint values were within the instrument's threshold. The comparable sample measurements also suggest that any difference in gloss (sheen) between the paint formulas is extremely subtle, and probably not visually perceptible.

There was a consistent distinction between the gloss measurements taken on the black vs. the white backgrounds. In six out of seven samples the white measurement was a higher than the black: this might be explained by the propensity for black to absorb light (therefore – decreasing the amount of reflected light). and white to reflect light.

⁹⁰ The equipment was loaned by Minolta Corporation, Northeast Regional Instruments Systems Division.

Although Benjamin Moore would not reveal the actual gloss measurement for their Muresco® product, both Dunn & Edwards and Duron provide the gloss data on their product information sheets for comparable interior flat wall paints. For Dunn & Edwards' *Decovel® Interior Velvet Flat Wall Paint* the finish is described as "Flat. 2% on a 85° meter". (Gloss values may be described as either percentages or gloss units, both terms use the same values.) According to the Duron Technical Data sheet for *their Plastic Kote® Interior Flat Acrylic Latex* the 'sheen' of the paint is 1.5-2.5%. The term 'sheen' in this case implies that the measurement was taken using the 85° geometry setting on the gloss meter⁹¹. (See Appendix 8.1 for copies of the Product Information Technical Data sheets.) The gloss values for the traditional and modified distempers (2.5-3.5) fall within the high end of the measurement range for the commercial flat paints described above. The mean gloss values for the Muresco® paint were 2.8 (measured on the black substrate) and 2.9 (measured on the white substrate). These higher values may suggest that the gloss meter used to carry out the measurements for this thesis produced slightly higher readings.

It is interesting that the perceived impression of distemper is often considered to be unusually luminescent and matte, yet there was no distinction between the unmodified distemper and polymer dispersion paint specular reflectance measurements taken with the gloss meter. This suggests that some other optical phenomenon is contributing to distemper's distinct appearance, such as diffuse scattering. It is possible that physical differences between the titanium dioxide pigment (used in modern polymer dispersion paints) and calcium carbonate (the predominant

⁹¹ 'Sheen' is defined in *Matte Paint* as "an attribute of object mode of appearance which is similar to luster; gloss with poor distinctness-of image reflectance. Frequently, in the paint industry, sheen is used synonymously with 'low-angle sheen,' a characteristic where a material appears to be matte when illuminated and viewed near to the perpendicular, but appears to be glossy when illuminated and viewed at an angle near to the grazing angle, such a 85° off the perpendicular. Sheen is therefore frequently evaluated in terms of gloss measurements made on a 75° or 85° gloss meter." Hansen *et al.*, 532. The 85° geometry setting was confirmed with the Technical Support Department at Duron, personal conversation.

pigment in distemper) such as; particle size, shape, and translucency may directly effect the way light is scattered, absorbed and reflected throughout the paint films.

Marigo Stavridi, *et al.*, describe the combination of reflection mechanisms that contribute to the appearance of matte materials:

In the case of smooth surfaces, interface reflection gives the surface a mirror-like appearance. In body reflection, light penetrates the surface and undergoes scattering as a result of reflection and refraction caused by inhomogeneities within the surface medium. Part of this light can be absorbed or transmitted through the surface. The remaining light finds its way back to the interface and emerges as body reflection. As a result of the random subsurface scattering, the emerging rays are distributed in a wide range of directions, giving the surface a matte appearance. In many materials both surface and body reflection mechanisms coexist and together determine the surface reflectance properties.⁹²

Stavridi notes that in addition to the local reflectance properties of a material, its appearance is also determined by the angle of illumination and the roughness or texture of the surface.

3.3.2 Opacity (Contrast Ratio Measurement)

Opacity is defined as “[t]he ability of an object to absorb light such that a background substrate is obscured. This is opposed to transparency, which is the degree to which a material transmits light, allowing a background substrate to be seen.”⁹³ There are several factors that contribute to a paint film’s capacity to obscure the underlying substrate: the dispersion of the pigment particles, pigment particle size, refractive index of the pigment particles and of the binder, the scattering

⁹² Marigo Stavridi *et al.*, “Surface Bidirectional Reflection Distribution Function and the Texture of Bricks and Tiles,” *Applied Optics*. vol. 36, no. 16: 3717.

⁹³ Minolta Corporation, instruction manual for the CM-3600d spectrophotometer, under “Measuring Opacity” using the Spectra QC.

coefficients⁹⁴ of the pigment particles in the given medium, and the pigment volume concentration of the paint film.

The two most common approaches to evaluating the opacity of a paint film are measuring the contrast ratio and hiding power (described in Section 3.3.3). *Contrast ratio* is simply the ratio of reflectance of the paint film applied over a black substrate compared to its reflectance over a white substrate. The following equation is used to calculate the contrast ratio value.

$$\text{Opacity (\%)} = \frac{R_{\text{black}}}{R_{\text{white}}} \times 100 (\%)$$

According to Minolta Corporation, manufacturers of spectrophotometers with opacity measurement capabilities, “the white background [substrate] should reflect greater than 85% at all wavelengths; the black background [substrate] should reflect less than 5% at all wavelengths.”⁹⁵ This method is best suited for white paints, as any tinting pigments can effect the reflectance/absorption measurements. It should be noted that the variations in color between the warm calcium carbonate in the distemper samples and the cooler titanium dioxide in the polymer dispersion paint sample could directly affect the opacity results.

⁹⁴ “This function is a measure of the amount of light scattered at pigment/vehicle interfaces within the paint film. [The] coefficient is calculated via Kubelka Munk theory using the same reflectance measurements as contrast ratio. This function is influenced very little by contributions from light absorption and therefore most effectively expresses the performance of [the primary pigment] in a paint film. If a pigment gives a high scattering coefficient, then the potential opacity of a tinted paint containing that pigment is high. This function is expressed in terms of “per unit film thickness” usually corrected to a thickness that is relevant to real paint films.” Millennium Chemicals, Inc. website:

www.mic-global.com/Products+by+Type/Titanium+Dioxide++Paint+and+Coatings

The website for Cimprogetti lists the following scattering coefficients: ground calcium carbonate (the primary pigment used in the distemper samples) – 900-1700; precipitated calcium carbonate – 1700-2600; and titanium dioxide (one of the primary pigments used in commercial paints) - 5400-6800. Although these values do not refer to a relative binding medium, they clearly illustrate the superior hiding power/opacity that titanium dioxide would contribute to a paint film. Cimprogetti website:

www.cimprogetti.com/English/Products/PCC_product/PCC_Advantages

⁹⁵ Minolta Corporation, instruction manual for the CM-3600d spectrophotometer

Testing Procedure

To standardize the procedure for contrast ratio measurements, the paint films should be applied in a way that uniform film thickness can be achieved. In addition, standardized black and white substrates should be used, such as the Leneta Opacity Charts. The contrast ratio measurements were carried out on the same set of samples as the gloss measurements, (see Section 3.3 for a description of the sample preparation.)

The contrast ratio measurements were taken by Elaine Becker, Regional Manager, Northeast Instruments Division for Minolta Corporation, using a Minolta CM-508d spectrophotometer. Four measurements are used to calculate the contrast ratio (or % opacity) for each sample: the white background measurement, black background measurement; sample over white background, and sample over black background. The instrument displays the four values for each sample measured, in addition to the calculated contrast ratio.

Prior to carrying out measurements on the actual samples, the spectrophotometer is calibrated using both black and white color standards. Measurements are first taken of the black and white sample backgrounds, then the backgrounds are measured with both the black and white standards.

Results

Contrast ratio measurements were taken on both sets of the drawn down samples (one set made with a 3 mil clearance bar, the other with a 6 mil clearance bar). As one might expect the 3 mil set of samples produced slightly lower contrast ratio values than the 6 mil, indicating that the thinner paint films were more transparent. (*See Figure 6.2*) The relative values varied slightly between the

two sets of samples, suggesting that the film thickness may have been inconsistent. The two paints with the highest contrast ratio values were the Muresco® white ceiling paint and the synthetic distemper (14% Rhoplex AC-33 by volume - containing no gelatin). These two paints were ranked 1 and 2 for both sets of samples, however, the Muresco® ceiling paint was distinctly higher for the 3 mil samples, having a value of 95.23 in comparison to 87.63 for the synthetic distemper formula. The rankings were reversed for these two paints in the 6 mil set of samples, although the values were much closer; 98.32 for the Muresco®, and 98.84 for the synthetic distemper.

The two lowest contrast ratio values in both sets of samples were the distempers modified with 10 and 20% Rhoplex AC-33 (% by volume), suggesting that the lower pigment to volume concentrations have reached a point at which the hiding power of the paint films are compromised. The three remaining formulas (the unmodified distemper, and the 2% and 5% modified with AC-33) had comparable values among the 3 mil set of samples ranging from 80.93 (unmodified distemper) – 82.88 (2% AC-33 by volume). The unmodified distemper has the highest contrast ratio (97.86) among the three in the 6 mil set of samples, with the 5% having a significantly lower value of 93.61.

The approximate pigment to volume concentrations (PVC) were calculated for each sample type.⁹⁶ (See Figure 6.3) Although the PVC value was not available for the Muresco® ceiling

⁹⁶ Notes regarding the PVC calculations: 1) The calcium carbonate putty was made using the following proportions: approximately (1000 g of dry calcium carbonate + 570 g of water) resulting in about 1062 ml of putty (the calculated density of the putty is ~ 1.48 g/ml). The volume of water (d = 1g/ml) was subtracted from the final putty volume (1062 – 570 = 492), the difference being the volume of the calcium carbonate. Therefore, every ml of putty contained ~ .46 ml of calcium carbonate. Similar calculations were used to determine the amount of gelatin and Rhoplex AC-33 solids per ml of solution. Both solutions had approximate densities of 1g/ml.

paint it is estimated to be in the range of 70-80%.⁹⁷ There is a correlation between the PVC values of the paint formulas and the opacity measurements. (See Figure 6.4) The general trend is the higher the PVC, the higher the contrast ratio. The one exception to this is the Muresco® white ceiling paint, which probably has the lowest PVC value among the sample formulas. The superior hiding power is most likely due to the presence of titanium dioxide pigment, which as previously mentioned, has a much higher scattering coefficient than calcium carbonate, significantly enhancing the polymer dispersion paint film's hiding power.

3.3.3 Relative Hiding Power / Leveling (Visual Evaluation of Brushouts)

The purpose of this set of tests was to visually evaluate the appearance of the various formulations brushed out onto Leneta charts. There are many limitations to regulating the application procedure when brushing the samples out by hand. There are a variety of potential inconsistencies: lack of uniform film thickness; unequal amounts of paint applied to each sample surface; irregular brushstrokes; and different spreading rates. In an effort to standardize the brushout procedure, a method was adapted from the ASTM Standard Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts (D 344 – 89). (See Appendix 8.2 for a copy of the ASTM test, or Section 3.3 for a description of the application procedure.) Due to the inevitable application discrepancies, the set of samples were deemed more suitable for qualitative evaluation rather than quantitative.

⁹⁷ Information obtained from the PaintQuality.com website (www.pqi-anz.paintquality.com/doi/binder/asp) stated that the typical PVC for a flat paint ranges from 38-80%. Since commercial ceiling paints tend to have slightly higher PVC concentrations than flat wall paints, it was assumed that the value for the Muresco paint would fall towards the high end of the range noted above. In addition, an approximate PVC value was calculated for a commercially available flat paint by using the % solids by weight information presented in the product information sheet for Dunn & Edwards *Decovel* Interior Velvet Flat Wall Paint. The value was 68% pigment concentration by weight. (See Appendix 8.1 for a copy of the product information sheet.)

The terms 'opacity' and 'hiding power' are often used interchangeably; however, there were two citations found that made a distinction between them. In *Matte Paint* hiding power is defined as the ability of a paint to obscure the underlying surface (substrate), whereas opacity is a term used to describe the degree to which a material obscures the substrate.⁹⁸ This suggests that opacity is a quantitative as well as a qualitative term. In acknowledgment of this distinction, the term hiding power will be used for the qualitative evaluations. An alternative definition was provided on the website for Millenium Chemicals, Inc:

The hiding power of a paint is defined as the area that a unit volume of wet paint will cover at a film thickness sufficient to produce a contrast ratio of 98% when the film has dried. 98% contrast ratio is used, as it is the limit beyond which any further increase in contrast ratio is not visually detectable by a trained eye. This, therefore, represents a standard definition of full opacity. Because of its basis on contrast ratio, this function also gives a measure of "total opacity" including contributions from scattering and absorption.⁹⁹

Although this definition for hiding power is worth noting, it will not be applied in the context of this testing program.

Procedure

A scale of 0-5 was used to evaluate both the hiding power and leveling; 0 indicating an extremely poor rating and 5 indicating superior properties. In the case of hiding power, 0 would reflect a totally transparent paint film, where 5 would be assigned to a coating that completely obscured the graphic substrate (100% opacity). With the leveling, lower ratings were assigned to paint films that had clearly defined ridges (peaks and valleys) and streaks (linear variations in hiding power/film thickness that appeared to be directly related to the drag of the brush). Conversely, higher ratings were given to paint films that appeared to be almost completely level, with little or

⁹⁸ Hansen *et al.*, 529-30.

⁹⁹ Millennium Chemicals, Inc. website.

no remaining evidence of the brush strokes. This rating system was designed to evaluate the performance of the paint formulas as they compared to one another. The relative values are only significant in this limited context.

In addition to the visual evaluation described above, the measured densities and calculated spreading rates were considered when evaluating the results.

Results

The values for the actual spreading rates indicated that the brushout procedure was relatively successful in regulating the paint application: the rates fell within the range of $9.84 - 13.21 \text{ m}^2 / \text{L}$ (ASTM test D 344 – 89 recommends using a rate within the range of $9.8 - 19.6 \text{ m}^2 / \text{L}$).

The density values fell into two groups: 1) the higher density formulas were the unmodified distemper, synthetic distemper, and the modified distemper with 2% AC-33 – ranging from $1.44 - 1.47 \text{ gm/ml}$, respectively. 2) The lower density paints were the Muresco® Ceiling Paint, the modified distemper with 20% AC-33, and the modified distemper with 10% AC-33 – ranging from $1.34 - 1.38 \text{ gm/ml}$, respectively. The modified distemper with 5% AC-33 fell exactly in between with a density of 1.41 gm/ml . (*See Figure 6.5*) The density values appeared to be directly related to the hiding power and leveling of the paint films – generally, the higher density formulas performed better in both categories. (*See Figures 6.6 and 6.7*) The one clear exception is the Muresco® White Ceiling paint. This paint had the lowest density (1.34 gm/ml), however, it had superior hiding power. The presence of titanium dioxide in the Muresco® paint can account for this discrepancy. It is interesting to note, however, that the relatively low rating of the Muresco® leveling qualities is consistent with its low density.

Although the synthetic distemper fared well in the hiding power and leveling evaluation, its general appearance was not satisfactory. The paint films are inconsistent in appearance, some areas are more transparent than others, and there are tide lines around the edges of the test area that have slightly discolored. These suggest that the binder in this paint formula does not adequately remain in suspension and that the Rhoplex AC-33 may be settling out.

3.4 Evaluation of Mechanical Properties

Performance of the various paint formulations was also evaluated in terms of their durability. The relative strength of the paint films indicates how effective the binders are at adhering the pigment particles to one another (cohesion); and how well the paint films bond to the substrate (adhesion). It should be noted that these tests were carried out on relatively new samples, and so do not reflect any of the effects that aging might have on the paint binders, such as UV degradation. An additional element excluded from the testing program is the effect of moisture on the paint films. Both of these factors are worth incorporating into future experiments.

3.4.1 Abrasion (Resistance of Organic Coatings by the Taber Abraser)

Abrasion (or, resistance to wear) tests were used to assess the relative cohesive properties of the various paint formulations. The tests were carried out according to the procedure outlined in the *ASTM Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser* (Designation: D 4060 – 90). (See Appendix 8.2 for copies of the ASTM tests.) The paint samples are applied to a sturdy, level surface attached to a rotating platform on the Taber Abraser. The Taber Rotary Platform Double-head Abrasion Tester used for these tests has two arms, each

with a rotating wheel made of an abrasive material (there are a variety to choose from) that has been selected for its relative hardness. As the sample rotates the abrasive wheels gradually wear away the sample surface. An appropriate stopping point is selected, which in this case was the point at which the underlying substrate was exposed. The number of rotations it takes to reach this point is recorded for each sample. The sample is weighed before and after the abrasion test, and the difference in weight recorded. The wear index can then be calculated, which is basically the amount of sample lost per rotation.

$$I = (A-B) \times 1000 / C$$

I = wear index

A = weight of test specimen before abrasion, mg,

B = weight of test specimen after abrasion, mg, and

C = number of cycles of abrasion recorded

Sample Preparation

The substrate consisted of 1/8" Masonite that was cut into squares 4"x 4". A 1/4" diameter hole was drilled into the center of each Masonite square. The decision was made to attempt to replicate a method of paint application that would be used in the field. Therefore, the substrate was primed, and the paint formulations were brushed out (as opposed to being drawn down in a uniform thickness directly onto the substrate). BIN® Primer Sealer Stain-Killer (by William Zinsser & Co.) was selected as the primer. This is a high-quality product often used to prime walls in older buildings because of its ability to seal surfaces and obscure underlying stains. BIN® is a white pigmented shellac. The primer was tinted with red iron oxide pigment prior to application. This was done to create a visual contrast between the primer and the unpigmented (white) sample paint films. The color distinction made it possible to determine the point at which the sample paint layer had worn down completely, exposing the pink tinted primer. One coat of paint was applied using

a 2" nylon bristled brush, brushing first in one direction, then subsequently in a perpendicular direction to ensure complete coverage.

Upon the recommendation of an engineer at Taber, the Calibrase CS-10 abrading wheels were selected. These wheels are made of rubber and aluminum oxide abrasive particles, and are designed to be used with an applied load of 500-1000gm. The abrasive action of these wheels is rated as mild.

Procedure

The abrasion tests were carried out in the Grundy Laboratory at the Philadelphia University School of Textiles & Materials Technology, under the guidance of Laboratory Supervisor Janet Brady. The relative humidity in the Grundy Lab is maintained at 70%, creating a rather humid environment. The masonite substrate of the abrasion samples is a cellulose product, and so is prone to absorbing atmospheric moisture. To minimize the effect that this might have on the weight of the samples (artificially increasing the weight), they were weighed immediately before and after they were placed on the Taber Rotary Platform Double-head Abrasion Tester.

A 500gm load was applied to the arms holding the Calibrase abrading wheels. The machine was turned on and each cycle of abrasion (rotation) was counted. The rotations were stopped once the paint film had completely worn away a portion of the abrasive path. Due to variations in the paint film thickness across a given sample, and the difference in appearance between the paint formulations, it was difficult to determine a comparable ending point for each sample. The criteria used were: 1) that the paint layer appear to be compromised over the entire abrasive path (such as a distinct alteration in sheen – as the matte paint became burnished), and 2) that at least one section of the path be completely worn through. The samples were gently brushed to remove any

particulate, then reweighed. The difference in weight was calculated. The Calibrase abrading wheels were refaced (for 25 rotations – with the weight load removed) using an S-11 refacing disk prior to each sample run.¹⁰⁰

Results

The abrasion path is circular and approximately ½” wide; the diameter of the circle being about 1 ½” to the center of the path. The paint layers were most compromised along the central ¼” width of the path.

The wear index calculations indicate that the modified distemper with 2% AC-33 (by volume) was the most wear resistant formula having a mean wear index (*I*) of 25.87, followed by the 5% modified formula (*I* = 35.47), and the unmodified distemper (*I* = 40.31). (See Figure 6.8) From this point on the wear index value increased as the amount of AC-33 was increased for the gelatin/AC-33 formulas. The synthetic distemper samples showed extremely poor wear resistance, having a mean value of 929.12. The commercial Muresco® paint had a wear index of 77.44, significantly higher than any of the formulas containing gelatin.

The results suggest that the gelatin binder contributes significantly to the cohesive strength of the paint films. Although the slightly modified distempers indicate that Rhoplex AC-33 imparts additional wear resistance, there is a distinct threshold to the amount that can be added before the acrylic dispersion begins to have a detrimental effect (somewhere between 5-10%). The fact that

¹⁰⁰ A control sample was used to determine an appropriate applied weight load, and approximate number of abrasion cycles prior to testing.

the commercial paint had less wear resistance than any of the formulas containing gelatin indicates that gelatin has superior cohesive properties over the synthetic resin-based paints that were tested. When considering the poor performance of the synthetic distemper it should be noted that the concentration and amount of Rhoplex AC-33 may not have been within the recommended quantities for this particular application as determined by the manufacturer, Rohm & Haas.

It should also be kept in mind that consumers rate scrub resistance (the ability to withstand friction or abrasion in the presence of water) among the most valued properties they seek in an interior paint. It is possible that the paint industry is willing to compromise abrasion resistance for increased scrub resistance in their formulas. In addition, the commercial Muresco® paint is especially formulated as a ceiling paint, and so theoretically, would not need to be particularly resistant to abrasion. In the same vein, distemper paints were traditionally used on surfaces that were not subjected to constant wear and abrasion, such as ceilings and the upper portions of walls – above chair rails and wainscoting.

Two potential variables – inconsistent film thickness¹⁰¹ and subjective determination of the stopping point – are accounted for in the calculations for the wear index value. The calculation breaks down the results into the amount of weight lost per abrasive cycle. Therefore, if one sample was abraded for an excessive amount of cycles, there should have been an additional amount of weight lost (relative to each additional cycle), and so the wear index would value would not be significantly changed.

¹⁰¹ ASTM test D 4060 – 90 also suggests calculating the *Wear Cycles Per Mil*, however, in order to do this a precise measurement of the sample film thickness needs to be measured. Since the decision was made to brush out the paint layers, creating films with an inconsistent thickness, these measurements were not carried out.

3.4.2 Adhesion (Parallel Groove / Tape Test)

Adhesion tests were carried out to measure the relative adhesive properties of the paint formulations. The procedure was followed as dictated by ASTM Designation: D 3359 – 90 Standard Test Methods for Measuring Adhesion by Tape Test. *(See Appendix 8.2.)* In this test a cutting tool is used to incise a grid on the surface of a paint sample. A piece of tape is placed on top of the incisions, then peeled away. The surface is visually evaluated to assess the amount of paint lost around the incisions. A standardized numeric rating system is provided by ASTM, including visual guides.

Sample Preparation

The sample substrates were cast in plastic petri dishes creating round discs approximately 3 ½” in diameter. Two discs were cast for each type of paint formula, in addition to two controls. The decision was made to attempt to simulate typical field conditions; therefore, the substrate selected was a gypsum-based product, similar to a finish plaster. The material used was Perma-stone® *(see Appendix 8.1 for a copy of the MSDS and product information)*, an artist’s grade casting plaster that is enhanced to be water resistant, yet the surface can be painted with any water-based paint. As with the abrasion samples, the substrate surfaces were primed with BIN® primer prior to the paint application. Both the primer and paint formulas were brushed out, and so there is the potential for inconsistencies in the film thickness and leveling.

Both the substrate and primer were slightly tinted with inert pigments so that the different materials would be visually distinguishable from each other. The substrate was tinted green (using

Viridian Green – hydrated chrome oxide), and the primer tinted red (Venetian Red – a red iron oxide).

Procedure

In an attempt to make the parallel cuts more precise and repeatable, a cutting tool was used that has evenly spaced teeth (cutting edges). This ensures that the incisions are parallel, and if even pressure is applied – that the incisions are made to a comparable depth. The cutter selected had 11 teeth spaced approximately 1mm apart. This cutter is rated as ‘fine’, and is the type recommended in Standards for testing sample film thicknesses of 2 mils or less.¹⁰² The cross hatch cutting tool was used to incise two sets of parallel incisions penetrating the paint film on the sample, the incisions were made perpendicular to each other to create a grid. Several sets of grids were carried out on all of the sample discs. The four cleanest grids (having distinct incisions at approximately the same depth) were selected for each type of paint formula for evaluation.

The selected grids were numbered. A piece of Permacel 99 Adhesive Tape was cut to approximately 3” in length. The tape was placed in the center of the grid and pressure was evenly applied over the grid area using the eraser on the end of a pencil. The tape was left in place for 90 seconds then slowly pulled off of the sample surface at approximately 180° angle. The incised grid was then evaluated (with the aid of an illuminated magnifying glass) and rated according to the following scale outlined in ASTM test D 3359.

- 5B The edges of the cuts are completely smooth; none of the squares of the lattice is detached.*
- 4B Small flakes of the coating are detached at intersections; less than 5% of the area is affected.*
- 3B Small flakes of the coating are detached along edges and at intersections of cuts.*

¹⁰² Guidelines for selecting the appropriate tools were explained in the Byk Gardner Catalog (pp. 99-100), the company from which the Cross-Hatch Cutter Kit was purchased.

- The area affected is 5 to 15% of the lattice.*
- 2B The coating has flaked along the edges and on parts of the squares. The area affected is 15 to 35% of the lattice.*
- 1B The coating has flaked along the edges of cuts in large ribbons and whole squares have detached. The area affected is 35 to 65% of the lattice.*
- 0B Flaking and detachment worse than Grade 1.*

Results

When evaluating the adhesion results only losses at the paint / primer interface were considered, since the purpose of the test was to evaluate the relative adhesive strength of the various paint formulas – not the primer; any losses at the substrate / primer interface were ignored. The tinted primer made it clear where the paint failure had occurred.

Both the unmodified distemper and the Muresco® ceiling paint had mean values of 5B, with almost no distinguishable loss. (See Figure 6.9) The modified distemper containing 20% Rhoplex AC-33 had a mean value of 4.5B, while the 2%, 5%, and 10% (by volume) modified formulas had mean values of 4B. The synthetic distemper had the poorest rating, 2.5B. These results suggest that the addition of AC-33 does not necessarily contribute to the adhesive properties of the modified formulas, and may even have a detrimental effect.

Chapter 4

Conclusions and Recommendations

There were three primary objectives of this thesis: 1) to develop a practical and effective testing program for evaluating the optical and mechanical properties of traditional and modified distemper paints. 2) To determine whether or not there are measurable differences between a traditional distemper and a commercial flat polymer dispersion paint. 3) To establish whether or not the physical properties of a traditional distemper can be effectively enhanced without compromising its optical properties.

Optical Properties

There were quantifiable differences in the gloss measurements between the various paint formulas. however, the values fell within such a narrow range that it seems unlikely that these differences in sheen would be visually perceptible. It is interesting to note that the unmodified distemper and commercial white ceiling paint had exactly the same gloss measurements taken on both the black and white backgrounds: their values ranked third, behind the 5% modified distemper and 20% modified distemper which both had gloss readings that were lower (more matte). These results

suggest that the distinct appearance of traditional distemper paints is not sheer. The gloss meter measures specular reflectance; however, Stavridi *et al.* state that the appearance of matte surfaces is the combined effect of both specular reflectance and body reflectance (random subsurface light scattering).¹⁰³ It also seems likely that a significant component of distemper's appearance is attributable to the optical properties of the calcium carbonate, such as the scattering coefficient, pigment particle size and shape, and how these may contribute to the diffuse scattering in ways that are not measured by a gloss meter.

The opacity measurements (contrast ratio) and relative hiding power (visual evaluation) produced comparable results to each other - when the values were ranked in relative order. The commercial ceiling paint was most successful at obscuring the substrate in both sets of tests. This is not surprising, considering that this paint contains titanium dioxide – a white pigment specifically used for its superior hiding power. The synthetic distemper solution had comparable opacity measurements to the commercial ceiling paint, but ranked fourth in the brushout evaluations – below the traditional distemper and 2% modified formula. The traditional distemper, 2% and 5% modified formulas all had relatively similar results among these tests, while the 10% and 20% modified solutions consistently ranked the lowest (most transparent).

There was a correlation between the pigment to volume concentrations and the contrast ratios among the distemper paint formulas: in general, the higher the pigment content, the higher the contrast ratio. The results also indicated that somewhere in the range of 5-10% of the modified distemper volume lies the critical point at which the Rhoplex AC-33 additive begins to compromise the opacity/hiding power of the paint films. This suggests that the pigment to volume

¹⁰³ Stavridi *et al.*, 3717.

ratio has probably reached its threshold, where the additional binder begins to fill voids – compromising the dry hiding power, and rendering the paint film translucent.

The brushout evaluations indicated a relationship between the density of the wet paints and their ability to self-level, and obscure the underlying substrate as a dry film. The higher the density (which in most cases corresponded to the PVC values in terms of relative order), the better the paint formula performed in these two aspects. As with the opacity measurements, the Muresco® ceiling paint was the one exception. The Muresco® ceiling paint had the lowest density, but ranked highest in the hiding power evaluations. It should be noted however, that the Muresco® ceiling paint did not perform well in the self-leveling category, where its ranking did coincide with its relative density value.

In summary, there was no significant difference in gloss value between the various paint formulas. The opacity, hiding power, and leveling produced more distinct results. Although the commercial polymer dispersion paint clearly had superior hiding power (opacity), it showed relatively poor self-leveling. The unmodified and minimally modified distempers were less opaque, but produced superior leveling. Although the synthetic distemper fared well in all of the optical evaluations, the formula consistently ranked low in the mechanical tests. In addition, this formula had a tendency to form yellowish tide lines in areas where the paint was thickest – rendering its appearance unacceptable for conservation purposes.

Mechanical Properties

The 2% and 5% modified distemper formulas presented the best resistance to abrasion, followed by the unmodified distemper. The commercial polymer dispersion paint ranked 6th out of 7; the

only paint formula with worse abrasion resistance was the synthetic distemper. The unmodified distemper and commercial polymer dispersion paint were ranked the highest in terms of their adhesive properties: the 5% modified formula and synthetic distemper were ranked lowest. These results suggest that a minimal amount of Rhoplex AC-33 may enhance the abrasion resistance of distemper paint, but it may be at the expense of slightly compromised adhesive properties.

The mechanical tests illustrate the strength of gelatin as a paint binder – it surpassed the commercial polymer dispersion paint in both tests. However, these formulas were not evaluated in terms of their performance under humid conditions, prolonged exposure to ultra violet radiation, or scrubability - essential qualities in the overall performance of a paint. Although, the minimal addition of Rhoplex AC-33 did not significantly improve the adhesion and abrasion resistance of the modified distempers, it would be interesting to see if it improved the water resistance of the gelatin-based paints.

Recommendations for Future Testing

- 1) The need for water-related testing is discussed above and in previous sections. Gelatin has been proven to be extremely susceptible to shrinkage and swelling due to the absorption of atmospheric moisture, which eventually compromises the strength of the distemper paint film. Does Rhoplex AC-33 enhance the distempers' water resistance?
- 2) Although minimal amounts of Rhoplex AC-33 did not appear to have a detrimental effect on the optical properties of the paint, and slightly enhanced the abrasion resistance, it may be worth testing a variety of additives (both traditional and modern). When evaluating the different additives it would be interesting to use SEM images to investigate how the additives are effecting the paint films at a molecular level. Is the additive truly miscible in the formula?

Is it chemically bonding to the gelatin molecules? How are the interstices between pigment particles being filled as the pigment to volume concentration is being decreased?

- 3) It is essential that any distemper used in the field contain some sort of biocide to eliminate microbial attack of the gelatin. There are a variety of effective materials to choose from, but each may potentially effect the optical and/or mechanical properties of the paint film, and therefore warrants testing prior to recommendation.
- 4) There is a distinct difference in appearance between a traditional distemper paint formula and a modern polymer dispersion paint. This testing program indicated that there was no measurable difference in gloss, although there were some measurable differences in opacity. One obvious explanation for this is the presence of titanium dioxide in the modern paint. Titanium dioxide has a much higher scattering coefficient than the calcium carbonate in distemper. In addition, titanium dioxide is a much cooler white. But is there an additional optical phenomenon that contributes to the distinct luminosity of distemper? It would be essential to investigate alternative optical measurements, such as diffuse scattering.

The implemented testing program proved to be effective for this initial round of investigation. The experimental results produced sufficient data to draw preliminary conclusions about the properties of the various paint formulas. Although, many unanswered questions still remain, it is my hope that this thesis will inspire further research on the topic of traditional and modified distemper paints.

Chapter 5

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Chapter 6

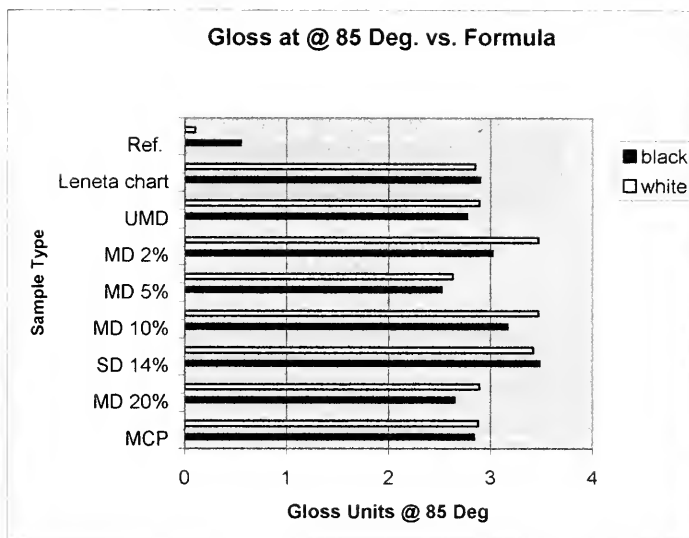
Figures

The following figures graphically display the experimental results and trends. Chapter 7 contains tables that present the corresponding data for each set of measurements.

Key to Figures

Paint Formula	Abbreviation
Unmodified Distemper (Binder: 14% gelatin, solids by weight)	UMD
Modified Distemper – 2% Rhoplex AC-33 (Binder: 14% gelatin + 2% Rhoplex, by volume)	MD 2%
Modified Distemper – 5% Rhoplex AC-33 (Binder: 14% gelatin + 5% Rhoplex, by volume)	MD 5%
Modified Distemper – 10% Rhoplex AC-33 (Binder: 14% gelatin + 10% Rhoplex, by volume)	MD 10%
Modified Distemper – 20% Rhoplex AC-33 (Binder: 14% gelatin + 20% Rhoplex, by volume)	MD 20%
Synthetic Distemper (Binder: 14% Rhoplex AC-33, solids by weight, no gelatin)	SD 14%
Muresco® White Ceiling Paint, a commercial flat polymer dispersion paint (Binder: vinyl-acrylic)	MCP

Figure 6.1 Ten gloss measurements were taken from both the black and white substrate areas for each paint formula. The values depicted in the chart reflect the mean. It is interesting to note that the unmodified distemper and commercial polymer dispersion paints had exactly the same mean values. All of the paint formula measurements fell into a fairly narrow range of 2.5-3.5 gloss units



(‘Ref.’ refers to the reference materials measured. The white measurement was taken on white cotton percale; the black measurement was taken on black melton wool.)

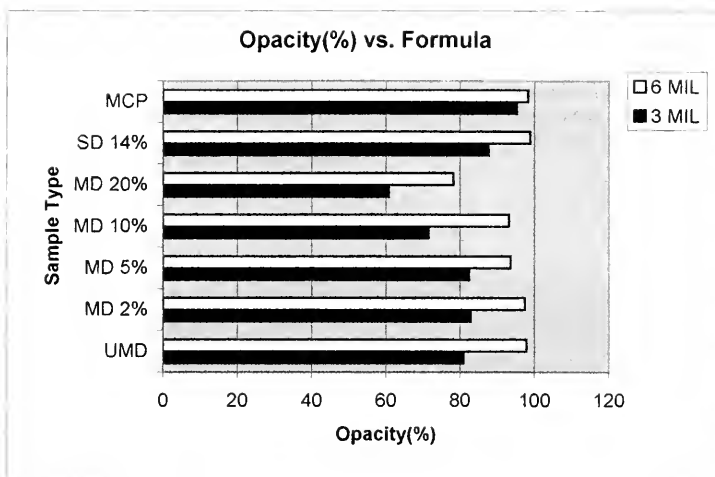


Figure 6.2: Opacity measurements for each paint formula were taken from both the 3 mil and 6 mil sample sets. (Note: 3 mil and 6 mil refers to the clearance of the draw down bar used to make the sample film, it does not reflect the thickness of the dried paint film.) The commercial polymer dispersion paint had the highest opacity value, followed by the synthetic distemper. The two lowest measurements were taken from the 10% and 20% modified distempers. These results suggest that a threshold lies between 5% and 10% where the amount of additional binder begins to compromise the paint films ability to obscure the underlying substrate.

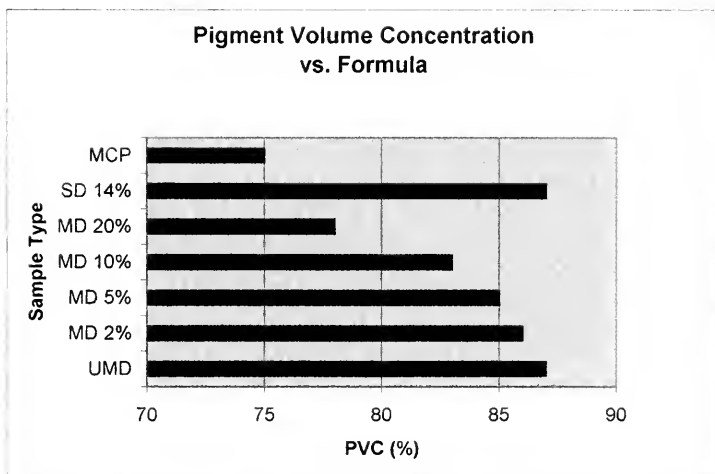
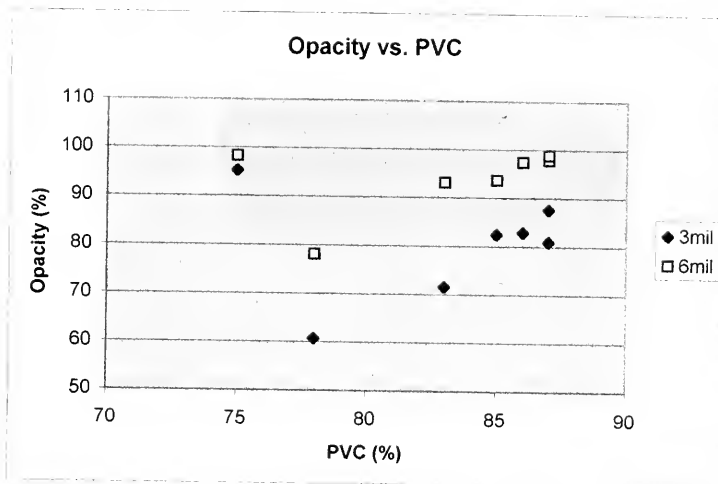


Figure 6.3: Approximate pigment volume concentrations for each of the paint formulas. Note that the unmodified and synthetic distempers were intentionally formulated to have the same pigment to volume concentration.

Figure 6.4 Comparison between the opacity measurements and pigment volume concentrations reveals a correlation between the two sets of data. The opacity measurements increase as the pigment volume concentration increases. The only exception to this trend is the commercial polymer dispersion paint, which has the highest opacity measurement while having the lowest pigment volume concentration. One possible explanation is the presence of titanium dioxide in the commercial paint formula, which is a white pigment specifically used for its superior hiding power.



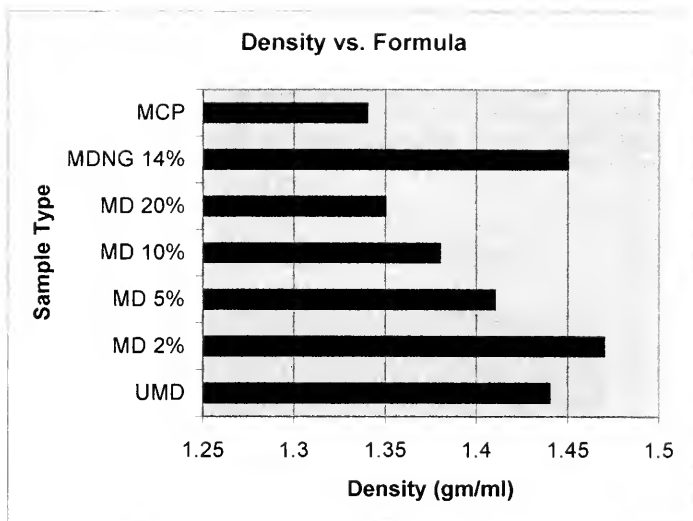


Figure 6.5: The density of each paint solution was measured. The 'MD NG 14%' is the synthetic distemper, made with 14% Rhoplex AC-33 (solids by weight) and no gelatin.

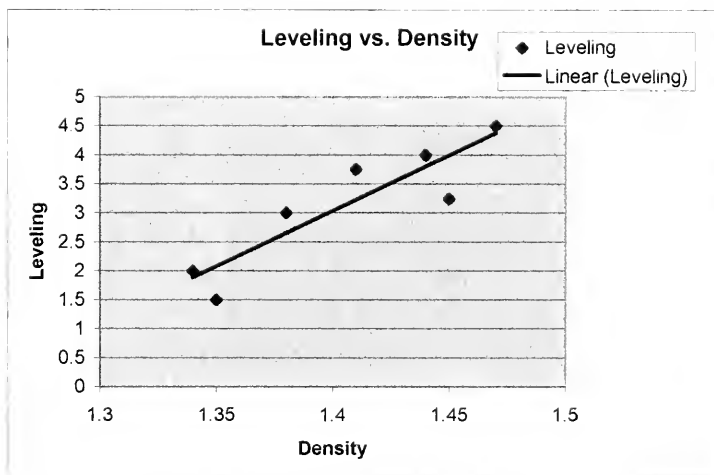
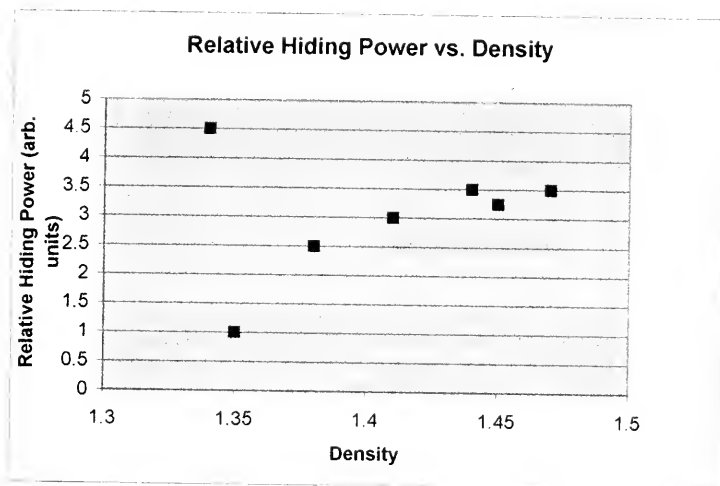


Figure 6.6: A comparison of the density measurements and the relative leveling results reveal a trend. As the density increases, the leveling properties improve (leveling was evaluated on a scale from 0-5, 5 being superior).



Figure 6.7: A comparison of the density measurements to each paint formula's relative hiding power shows a similar trend to the one illustrated in Figure 6.6. (The relative hiding power was rated on a scale of 0-5, 5 being superior). In six out of seven samples the relative hiding power improved as the density increased. The one result that clearly deviates from this trend is the commercial polymer dispersion paint, which had the highest rated hiding power while having the lowest density. This is probably due to the presence of titanium dioxide in the commercial paint formula. Titanium dioxide is a white pigment specifically added for its superior hiding power.



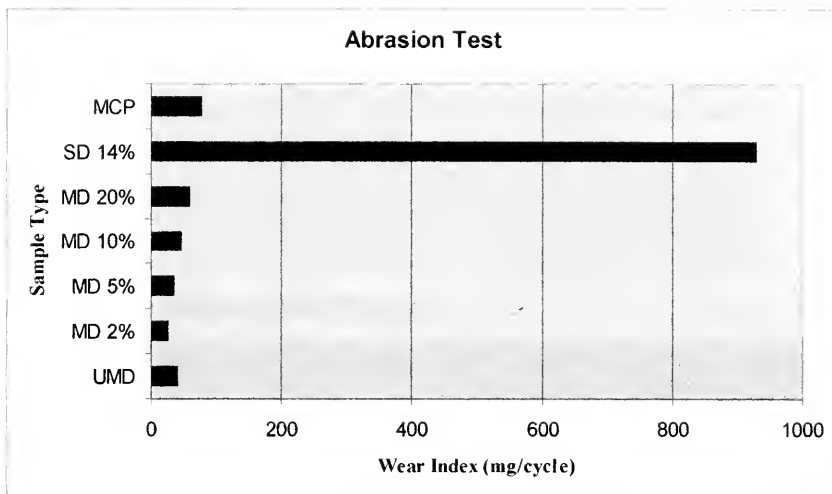


Figure 6.8: Abrasion tests were carried out using the Taber Abraser. The results are recorded as milligrams lost per wear cycle. The 2% and 5% modified solutions had the best abrasion resistance, however these formulas revealed only a slight improvement over the unmodified distemper. All of the distemper formulas performed better than the commercial flat polymer dispersion paint, with the clear exception of the synthetic distemper.

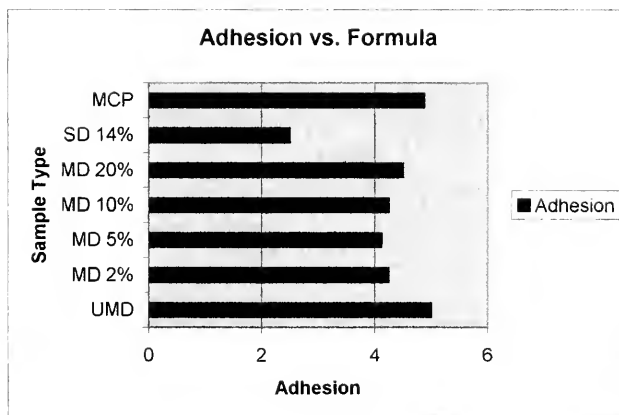


Figure 6.9: A parallel groove / tape test was used to evaluate the adhesive properties of the paint formulas. The unmodified distemper and commercial flat dispersion paint had superior adhesive properties (both having mean values of 5 when rated on a scale from 0-5). The poorer performances of the modified distempers suggest that the addition of Rhoplex AC-33 did not enhance the adhesive properties.

Chapter 7

Tables

Table 7.1: Thesis Experiments: Sample Preparation

<i>Experiment</i>	<i>No. of Samples*</i>	<i>Sample Substrate</i>	<i>Sample Dimensions</i>	<i>Substrate Tinted Y/N</i>	<i>Substrate Primed Y/N</i>	<i>Primer Tinted Y/N</i>	<i>Method of Paint Film Application Draw Down Bar / Brush</i>	<i>Destructive Y/N</i>
Gloss	14 (2 sets)	Leneta opacity charts Type 2A	5 ½"x 10"	N	N	N	draw down bar 1) 3mil clearance 2) 6 mil clearance	N
Opacity	14 (2 sets)	Leneta opacity charts Type 2A	5 ½"x 10"	N	N	N	draw down bar 1) 3mil clearance 2) 6 mil clearance	N
Relative Hiding Power	14 (2 sets)	Leneta display charts Type 8A	5 ½" x 10"	N	N	N	brush	N
Adhesion	14 (2 sets)	plaster	3" dia.	Y (green)	Y	Y (red)	brush	Y
Abrasion	14 (2 sets)	¼" masonite	4"x4" with a ¼"hole	N	Y	Y (red)	brush	Y

**Each set of samples should contain all seven paint formulations:*

- 1) *traditional distemper: 1 part 14% gelatin solution (solids by wt.) : 2 parts whiting soaked in water.*
- 2) *modified distemper: traditional distemper base + 2% Rhoplex AC-33 (by volume)*
- 3) *modified distemper: traditional distemper base + 5% Rhoplex AC-33 (by volume)*
- 4) *modified distemper: traditional distemper base + 10% Rhoplex AC-33 (by volume)*
- 5) *modified distemper: traditional distemper base + 20% Rhoplex AC-33 (by volume)*
- 6) *modified distemper: 1 part 14% Rhoplex AC-33 (solids by wt.) : 2 parts whiting soaked in water. Note – there is no gelatin in this formula.*
- 7) *commercial flat paint: Benjamin Moore's Muresco® white ceiling paint (a vinyl-acrylic)*

Table 7.2: Gloss Data

(Gloss measurements were taken with a Minolta Multi-Gloss 268 hand held gloss meter.)

<u>Paint Formula</u>	<i>Gloss Units Black Substrate (mean value)</i>	<i>Standard Deviation Black Substrate</i>	<i>Gloss Units White Substrate (mean value)</i>	<i>Standard Deviation White Substrate</i>
<i>Unmodified Distemper</i>	2.8	.47	2.9	.31
<i>Modified Distemper 2% AC-33</i>	3.0	.48	3.5	.40
<i>Modified Distemper 5% AC-33</i>	2.5	.36	2.6	.28
<i>Modified Distemper 10% AC-33</i>	3.2	.31	3.5	.56
<i>Modified Distemper 20% AC-33</i>	3.5	.25	3.4	.44
<i>Synthetic Distemper</i>	2.6	.40	2.9	.18
<i>Muresco® Ceiling Paint</i>	2.8	.36	2.9	.36
<i>Leneta Chart</i>	87.0	.99	85.5	.80
<i>White Cotton Percal</i>			0.5	.45
<i>Black Melton Wool</i>	0.1	0.		

- The mean values reflect the average of the 10 measurements on both the black and white substrates.

Table 7.3: Opacity Data (Contrast Ratios)

(The opacity measurements were taken using a Minolta CM-508d Spectrophotometer.)

<i>Formula</i>	<i>3 mil Set (units: % Reflectivity)</i>	<i>6 mil Set (units: % Reflectivity)</i>
<i>Unmodified Distemper</i>	80.93	97.86
<i>Modified Distemper 2% AC-33</i>	82.88	97.41
<i>Modified Distemper 5% AC-33</i>	82.43	93.61
<i>Modified Distemper 10% AC-33</i>	71.50	93.17
<i>Modified Distemper 20% AC-33</i>	60.75	78.11
<i>Synthetic Distemper</i>	87.63	98.84
<i>Muresco® Ceiling Paint</i>	95.23	98.32

Table 7.4: Pigment Volume Concentration and Density Data

<i>Paint Formula</i>	<i>Approximate Pigment Volume Concentration %</i>	<i>Density g/ml (mean value)</i>
<i>Unmodified Distemper</i>	87.	1.44
<i>Modified Distemper 2% AC-33</i>	86.	1.47
<i>Modified Distemper 5% AC-33</i>	85.	1.41
<i>Modified Distemper 10% AC-33</i>	83.	1.38
<i>Modified Distemper 20% AC-33</i>	78.	1.35
<i>Synthetic Distemper</i>	87.	1.45
<i>Muresco® Ceiling Paint</i>	70-80? estimated	1.34

- The estimated pigment volume concentration for the Muresco® Ceiling Paint is based on the high end of PVC values given for typical flat commercial paints. (The manufacturer, Benjamin Moore, would not reveal the actual PVC value.)
- The density mean values reflect the average of three measurements for each paint formula.

Table 7.5: Brushout Evaluation Data

(Adapted from ASTM Test D 344 – 89: Standard Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts)

<i>Sample Type</i>	<i>Actual Spreading Rate</i>	<i>Relative Hiding Power</i>	<i>Relative Leveling</i>
<i>Unmod. Distemper a</i>	10.62 m ² /L	3.5	4
<i>Unmod. Distemper b</i>	10.79 m ² /L	3.5	4
<i>Mod. Dist. 2% AC-33 a</i>	10.47 m ² /L	3.5	4.5
<i>Mod. Dist. 2% AC-33 b</i>	10.42 m ² /L	3.5	4.5
<i>Mod. Dist. 5% AC-33 a</i>	11.44 m ² /L	3	3.75
<i>Mod. Dist. 5% AC-33 b</i>	9.84 m ² /L	3	3.75
<i>Mod. Dist. 10% AC-33 a</i>	11.78 m ² /L	2.5	3
<i>Mod. Dist. 10% AC-33 b</i>	10.23 m ² /L	2.5	3
<i>Mod. Dist. 20% AC-33 a</i>	13.21 m ² /L	1	1.5
<i>Mod. Dist. 20% AC-33 b</i>	11.56 m ² /L	1	1.5
<i>Mod. Dist. 14% AC-33 a</i>	10.17 m ² /L	3.25	3.25
<i>Mod. Dist. 14% AC-33 b</i>	10.07 m ² /L	3.25	3.25
<i>Muresco® Ceiling Paint a</i>	11.44 m ² /L	4.5	2
<i>Muresco® Ceiling Paint b</i>	11.17 m ² /L	4.5	2

- The relative hiding power and leveling were rated on a scale from 0-5, 5 being superior.

Table 7.6: Abrasion Test Data

(ASTM Test D 4060 – 90: Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser)

<i>Paint Formula</i>	<i>Wear Index (mg/cycle)</i>	<i>Mean Value</i>
<i>Unmod. Distemper</i> <i>a</i>	40.47	40.31
<i>b</i>	40.15	
<i>Mod. Dist. 2% AC-33</i> <i>a</i>	22.74	25.87
<i>b</i>	29.00	
<i>Mod. Dist. 5% AC-33</i> <i>a</i>	35.00	35.47
<i>b</i>	35.94	
<i>Mod. Dist. 10% AC-33</i> <i>a</i>	43.95	44.98
<i>b</i>	46.00	
<i>Mod. Dist. 20% AC-33</i> <i>a</i>	53.69	58.08
<i>b</i>	62.47	
<i>Mod. Dist. 14% AC-33</i> <i>a</i>	802.85	929.12
<i>b</i>	1055.38	
<i>Muresco Ceiling Paint</i> <i>a</i>	74.44	77.44
<i>b</i>	80.43	

- The wear index reflects the milligrams of paint lost per wear cycle.

Table 7.7: Adhesion Test Data

(ASTM Test D3359 – 90: Standard Test Methods for Measuring Adhesion by Tape Test)

<i>Sample Type</i>	<i>Wear Index</i>	<i>Mean</i>
<i>Unmod. Distemper</i>	5B	5B
<i>a</i>		
<i>b</i>	5B	
<i>c</i>	5B	
<i>d</i>	5B	
<i>Mod. Dist. 2% AC-33</i>	4B	4B
<i>a</i>		
<i>b</i>	5B	
<i>c</i>	4B	
<i>d</i>	4B	
<i>Mod. Dist. 5% AC-33</i>	4B	4B
<i>a</i>		
<i>b</i>	5B	
<i>c</i>	4B	
<i>d</i>	3.5B	
<i>Mod. Dist. 10% AC-33</i>	4B	4B
<i>a</i>		
<i>b</i>	5B	
<i>c</i>	4B	
<i>d</i>	4B	
<i>Mod. Dist. 20% AC-33</i>	4B	4.5B
<i>a</i>		
<i>b</i>	5B	
<i>c</i>	5B	
<i>d</i>	4B	
<i>Mod. Dist. 14% AC-33</i>	2B	2.5B
<i>a</i>		
<i>b</i>	3B	
<i>c</i>	2.5B	
<i>d</i>	2.5B	
<i>Muresco® Ceiling Paint</i>	5B	5B
<i>a</i>		
<i>b</i>	5B	
<i>c</i>	4.5B	
<i>d</i>	5B	

- The adhesion results were based on the rating system described and illustrated in the ASTM standards. The scale ranged from *0B* extreme flaking and loss to *5B* virtually no loss.

Chapter 8

Appendices

8.1 Product Literature and Material Safety Data Sheets

Features

- ▲ Features solid hiding and easy application.
- ▲ Resists spattering when applied with a roller.
- ▲ Tones down ceiling glare and provides maximum diffused light.
- ▲ Provides a beautiful uniform flat finish.

General Description

A premium quality vinyl-acrylic coating especially formulated for ceilings.

Recommended For:

Residential or commercial applications where a premium quality finish is desired.

For new or previously painted plaster, wallboard, masonry and wallpapered surfaces, and acoustical ceiling tile and plaster.

Limitations:

- Do not apply when air and surface temperatures are below 50°F (10°C)
- Not available in all areas.

Product Information
Colors: —Standard:

White 258-01 or Classic Ceiling White 258-04
 (Classic Ceiling White or White may be tinted with up to 2.0 fl. oz. of Benjamin Moore Color Preview™ colorants per gallon.)

—Tint Bases:

Not available

—Special Colors:

Contact your Benjamin Moore & Co. representative

Certification:

Formulated without lead, mercury, or chromates.

Federal Specifications Generic Equivalent

TT-P-650-C

Technical Assistance

Available through your local authorized independent Benjamin Moore & Co. dealer. For the location of the dealer nearest you, call 1-800-826-2623, see www.benjaminmoore.com, or consult your local Yellow Pages.

Technical Data Classic Ceiling White

Vehicle Type	Vinyl-Acrylic Latex
Pigment Type	Titanium Dioxide
Volume Solids	29%
Theoretical Coverage At Recommended Film Thickness	400 – 450 Sq. Ft.
<i>Depending on surface texture and porosity Be sure to estimate the right amount of product for the job. This will ensure color uniformity and minimize the disposal of excess paint.</i>	
Recommended Film Thickness – Wet	3.8 mils
– Dry	1.1 mils
Dry Time @ 77° F (25°C) @ 50% RH	— Set To Touch 1 Hour
	— Dry To Touch 2 Hours
	— To Recoat 2 Hours
	— To Service 2 Hours
Dries By	Evaporation, Coalescence
Viscosity	100 ± 3 KU
Flash Point (Seta)	None
60° Specular Gloss	Flat
Surface Temperature at application – Min.	50° F
– Max.	90° F
Thin With	Clean Water
Clean Up Thinner	Clean Water
Weight Per Gallon	11.5 lb.
Storage Temperature – Min.	40° F
– Max.	90° F
Volatile Organic Compounds (VOC)	
<i>Unthinned, this product is formulated not to exceed 250 Grams/Liter**</i>	

** Contact Benjamin Moore & Co. for actual values, which may or may not be substantially less than stated

Surface Preparation

Surfaces to be primed must be clean, dry, and free of wax, grease, dust, mildew, water soluble materials, and scaling paint. Glossy areas should be dulled.

Unpainted Surfaces & Masonry: New Plaster or masonry surfaces must be allowed to cure (30 – 60 days) before priming. All surfaces must be thoroughly brushed with stiff fiber bristles to remove loose particles.

Repainted Surfaces: Remove any peeling or scaling paint, and sand areas to feather edges smooth with adjacent surfaces.

Mildew: If mildew is present, it must be removed by scrubbing with a commercial mildew wash, or it will continue to grow through the fresh coating. If mildew is widespread, the use of power wash equipment is suggested. CAUTION: Use rubber gloves, work goggles and protective clothing when applying mildew wash. Follow manufacturer's directions.

Difficult Substrates: Benjamin Moore offers a number of specialty primers for use over difficult substrates such as bleeding woods, grease, crayon markings, hard glossy surfaces, galvanized metal, or other substrates where paint adhesion or stain suppression is a particular problem. Your Benjamin Moore dealer can recommend the right problem-solving primer for your special needs.

Primer/Finish Systems

For best hiding results, tint Regal® FirstCoat® (216) or BENJAMIN MOORE FRESH START® All Purpose 100% Acrylic Primer (023) to the approximate shade of the finish coat. Apply primer before and after filling nail holes, cracks and other surface imperfections.

Wood, New:

Primer: Benjamin Moore FRESH START All-Purpose Alkyd Primer (024)

Finish: 1 or 2 coats Moore's Muresco Ceiling White (258)

Wood, Repaint:

Primer: No primer needed

Finish: 1 or 2 coats Moore's Muresco Ceiling White (258)

Plaster/Drywall, New:

Primer: Regal FirstCoat (216) or BENJAMIN MOORE FRESH START® All Purpose 100% Acrylic Primer (023) **Finish:** 1 or 2 coats Moore's Muresco Ceiling White (258)

Plaster/Drywall, Repaint:

Primer: Regal FirstCoat (216) or BENJAMIN MOORE FRESH START® All Purpose 100% Acrylic Primer (023)

Finish: 1 or 2 coats Moore's Muresco Ceiling White (258)

Masonry, New:

Rough or Pitted Masonry:

Primer: Moorcraft® Super Craft™ Latex Block Filler (285)

Finish: 1 or 2 coats Moore's Muresco Ceiling White (258)

Masonry and Unpainted (Including Unglazed Brick):

Primer: Not required if surface is firm. Loose, sandy masonry should be cleaned thoroughly to remove surface particles, allowed to dry, then primed with BENJAMIN MOORE FRESH START® All Purpose 100% Acrylic Primer (023)

Finish: 1 or 2 coats Moore's Finish Paint Muresco Ceiling White (258)

Masonry, Repaint (Including Unglazed Brick): A common finish paint failure on masonry construction is peeling and scaling, often caused by painting over heavy chalk deposits. The most practical and efficient way to remove this substance is with high pressure spray equipment (not for interior). Multiple coats of paint that are in an advanced state of deterioration or prior applications of cement based coatings must be removed to a sound substrate. Sand blasting or using a mechanical grinder are effective means of preparation. Surfaces should then be primed with a chalk binding primer such as Moore's Alkyd Masonry Sealer (C077) — White (C077-01) or Clear (C077-00) or Moore's Acrylic Masonry Sealer (066) **Finish:** 1 or 2 coats Moore's Muresco Ceiling White (258)

Metal Surfaces: All ferrous metal surfaces must be free of rust. Wipe all metal surfaces with mineral spirits to remove any oily, greasy residue. Solvent and rags should be changed frequently.

Primer: 1 or 2 coats IronClad® Latex Low Lustre Metal and Wood Enamel (363)

Finish: 1 or 2 coats Moore's Muresco Ceiling White (258)

Application

Mixing of Paint: Stir thoroughly before and occasionally during use. Do not add oil colors or solvents. Apply with a quality synthetic brush, short or medium nap roller, pad, or spray.

Do not apply when air and surface temperatures are below 50° F (10° C).

Spray, Conventional: see Thinning/Cleanup

Spray, Airless: Fluid Pressure — 1,500 to 2,000 PSI.
Tip — .018 Orifice, Filter — 50 mesh.

Thinning/Cleanup

Thinning is unnecessary, but if required to obtain desired application properties, a small amount of clean water may be added. Never add other paints or solvents. Wash painting tools in warm soapy water immediately after use. Spray equipment should be given a final rinse with mineral spirits to prevent rusting.

USE COMPLETELY OR DISPOSE OF PROPERLY. Dry, empty containers may be recycled in a can recycling program. **Local disposal requirements vary; consult your sanitation department or state-designated environmental agency for more information on disposal options.**

Environmental & Safety Information

Use only with adequate ventilation. Do not breathe spray mist or sanding dust. Avoid contact with eyes and prolonged or repeated contact with skin. Wear eye protection and gloves during application or sanding. dust/particulate respirator approved by NIOSH should be worn while sanding or spraying. Close container after each use.

FIRST AID: If you experience difficulty in breathing, leave the area to obtain fresh air.

IN CASE OF SPILL: — Absorb with inert material and dispose of as specified under Thinning/Cleanup.

Hazardous Materials Identification System® (NFPA)

Health	1	Flammability	0
Reactivity	0	Personal protection	

0 = Minimal, 4 = Severe Hazard

KEEP OUT OF REACH OF CHILDREN

Protect from freezing.

Material Safety Data Sheets available on request from your servicing dealer.

WELDING MEDIA: STAIN DO NOT WELD AFTER 3"
FURNACE FIRE AND EXPLOSION HAZARDS:
Sealed drums may leak when product turns.
Sealed containers may burst if exposed to extreme heat or fire.
SPECIAL FIRE FIGHTING PROCEDURES:
Cool exposed containers with water. Use self-contained breathing apparatus.

SECTION V HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE - ACUTE:
Inhalation - Causes nose and throat irritation.
Inhalation - Causes lung irritation.
Skin and Eye Contact - Primary irritation.
Ingestion of large amounts could cause serious injury.
EFFECTS OF OVEREXPOSURE - CHRONIC:
None Known
MEDICAL CONDITIONS PRONE TO AGGRAVATION BY EXPOSURE:
None expected when used in accordance with Safe Handling and Use
Information (Section VIII).
PRIMARY ROUTE(S) OF ENTRY: DERMAL INHALATION INGESTION
EMERGENCY AND FIRST AID PROCEDURES :
Inhalation - Remove to fresh air. Get medical help for any breathing
difficulty.
Eye Contact - Flush thoroughly with water. Call physician.
Skin Contact - Wash with soap and water.
Ingestion - Drink 1 or 2 glasses of water to dilute.
DO NOT induce vomiting. Call physician.

SECTION VI REACTIVITY DATA

STABILITY: STABLE HAZARDOUS POLYMERIZATION WILL NOT OCCUR
CONDITIONS TO AVOID: Elevated temperatures
HAZARDOUS DECOMPOSITION PRODUCTS:
Burning may produce carbon dioxide and carbon monoxide.
INCOMPATIBILITY (MATERIALS TO AVOID): None reasonably foreseeable.

SECTION VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:
Flush with water. Absorb with sawdust or rags.
WASTE DISPOSAL METHOD:
Conventional procedures in compliance with local, state and federal
regulations. Do not incinerate sealed containers.

SECTION VIII SAFE HANDLING AND USE INFORMATION

RESPIRATORY PROTECTION:
Use NIOSH approved respirator specified for protection against paint spray
mist and sanding dust in restricted or confined areas.
VENTILATION:
Adequate to maintain working atmosphere below T.L.V. and L.E.L.
(See Sect. II for ingredient data and concentrations). Mechanical exhaust
may be required in confined areas.
PROTECTIVE GLOVES: Waterproof during repeated contact.
EYE PROTECTION : Splash goggles or safety glasses with side shields.
OTHER PROTECTIVE EQUIPMENT: Clothing adequate to protect skin.
HYGIENIC PRACTICES:

Remove and wash clothing before reuse. Wash hands before eating, smoking or using the washroom.

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE:

Do not throw or drop containers.

OTHER PRECAUTIONS :

Avoid contact with eyes and prolonged contact with skin or breathing of spray mist or sanding dust.

Close container after each use. Keep out of reach of children. Do not take internally.

SECTION XX

HMIS (Hazardous Materials Identification System)(R) NPCA
HMIS is a recognized workplace Hazard Communications System as required by OSHA (29 CFR 1910.1200). Information on establishing a compliant hazardous communication program using HMIS is available from:

American Labelmark Co., Inc., Labelmaster Division
5724 N. Pulaski Rd., Chicago, IL 60646
1-800-621-5808

The ratings assigned by Benjamin Moore & Co. are only suggested ratings; the contractor/employer has ultimate responsibility for HMIS rating where this system is used.

PERSONAL PROTECTION: This code is left blank on Benjamin Moore & Co. MSDS's as it depends on application technique and the workplace ventilation. Please read Sections II through IX of this MSDS before deciding on appropriate protective equipment and beginning work. There are codes available for this section which can be obtained from Labelmaster.

Note: There are no SARA reportable materials in this product.

DISCLAIMER

The information contained herein is presented in good faith and believed to be accurate as of the effective date shown above. This information is furnished without warranty of any kind. Employers should use this information only as a supplement to other information gathered by them and must make independent determination of suitability and completeness of information from all sources to assure proper use of these materials and the safety and health of employees. Any use of this data and information must be determined by the user to be in accordance with applicable federal, state and local laws and regulations.

NOTICE: Removal of old paint by sanding, scraping or other means may generate dust or fumes which contain lead. Exposure to lead dust or fumes may cause adverse health effects, especially in children or pregnant women. Controlling exposure to lead or other hazardous substances requires the use of proper protective equipment, such as a properly fitted respirator (NIOSH approved) and proper containment and cleanup. For additional information, contact the USEPA/Lead Information Hotline at 1-800-LEAD-FYI.

DESCRIPTION: **DECOVEL** is a premium acrylic copolymer flat wall paint which produces a soft velvet finish combining exceptional hide with good stain resistance and washability. It is easy to apply, dries quickly and has low odor. **DECOVEL** is designed to provide long-lasting protection for interior walls, ceilings and other properly prepared and primed surfaces.

SPECIFICATIONS

SOLVENT TYPE

Waterborne

RESIN TYPE

Acrylic copolymer

FINISH

Flat. 2% on a 85° meter.

COLORS

Stock colors: White, Navajo White, Pearl White, Cottage White, Swiss Coffee, Black and 8 additional colors. Other colors can be special ordered or store mixed.

BASES

Light, medium, ultra deep

VISCOSITY AT 77°F (25°C)

95-100 Ku

VOC CONTENT

65 g/L (as supplied)

SOLIDS BY VOLUME

44.0%

SOLIDS BY WEIGHT

60.0%

WEIGHT PER GALLON

11.90 lbs.

COMPOSITION BY WEIGHT

Pigment - 41.0%

Vehicle - 59.0%

*Prime pigments 21.0

Acrylic vinyl resins..... 19.0

Reinforcing pigments ... 20.0

Water & additives..... 40.0

* Prime pigments include titanium dioxide (TiO₂), plus all other pigments directly adding to the hiding power of this paint.

RECOMMENDED FILM THICKNESS PER COAT

Wet: 3.2 mils

Dry: 1.5 mils

PRACTICAL COVERAGE PER COAT AT RECOMMENDED DRY FILM THICKNESS

300-450 sq. ft. per gallon, depending on surface conditions.

AVERAGE DRY TIME AT 77°F (25°C)

To touch: 1-2 hours

Tack-free: 1-2 hours

Recoat: 4 hours

To handle: 8 hours

APPLICATION EQUIPMENT

Brush, roller, airless spray

PACKAGING

Quart, one-gallon, five-gallon containers

FDA

Meets FDA guidelines for application to direct food contact surfaces.

MATERIAL SAFETY DATA SHEET

Form #1

SURFACE PREPARATION

All surfaces must be cured, clean, dry, and free from dirt, dust, rust, stains, grease, oil, mildew, wax, efflorescence and other contaminants. Remove all loose, peeling, or chalky paint by sanding, scraping, wire-brushing or other appropriate methods. Repair all cracks, holes, and other surface imperfections with a suitable patching material. Repaired surfaces should then be sanded, cleaned, and spot-primed with a suitable primer or sealer. Glossy surfaces should be dulled to provide a roughened surface for good adhesion.

SPECIAL INSTRUCTIONS

- If the air or surface temperature is between 37° and 50°F, add **Lotemp (W 201-33) - Cold Weather Reducer** per label directions.
- Do not apply when the air or surface temperature is below 37°F.

THINNING RECOMMENDATIONS

Brush application: Up to 1/2 pint of water per gallon.

Roller application: Up to 1/2 pint of water per gallon.

Spray application: Up to 1 pint of water per gallon.

CLEANUP

Water

PRIMERS

DRYWALL

Textured:

Vinylastic (W 101)

Untextured:

Vinylastic (W 101)

Skim-coated:

Vinylastic (W 101) or Walltone (W 420)

MASONRY

Plaster:

Vinylastic (W 101) or Alkylseal (E 28-1)

Tilt-up concrete:

Super-Loc (W 718) or Eff-Stop (W 709)

Poured-in-place:

Super-Loc (W 718) or Eff-Stop (W 709)

Concrete block:

Blocfil (W 304) or (W 305)

Brick:

Super-Loc (W 718) or Eff-Stop (W 709)

WOOD

Trim, doors:

Unikote (W 707), M-P Prime (W 713) or Super U-365 (E 22-1)

SYNTHETIC WOOD

Masonite:

Unikote (W 707) or Super U-365 (E 22-1)

Hardboard:

Unikote (W 707) or Super U-365 (E 22-1)

METAL

Ferrous:

Corrobar (43-5), Bloc-Rust (43-4)

Nonferrous:

M-P Prime (W 713), Versaprime (42-44) or Galv-Alum (QD 43-7)

Galvanized:

M-P Prime (W 713), Versaprime (42-44) or Galv-Alum (QD 43-7)

**INTERIOR FLAT ACRYLIC LATEX
PINTURA MATE DE ACRÍLICA
DE LÁTEX PARA INTERIORES**

TECHNICAL DATA

10406 Tucker Street • Beltsville, Maryland 20705 • (301) 937-4700
1415 Constitution Road • Atlanta, GA 30316 • (404) 241-7722

IDEAL FOR:

- Interior
- Ceilings
- Walls
- Plaster
- Masonry
- Wallboard

RESISTANT TO:

- Spatter During Application
- Household Dirt & Stain Absorption
- Hand Washings
- (See Washing Instructions)

FEATURES:

- Premium Quality
- Excellent Hiding
- Easy to Apply
- Low Odor
- Elegant, Flat Finish

IDEAL PARA:

- Interiores
- Cielos rasos
- Paredes
- Enlucido
- Mampostería
- Pared de cartón de yeso

RESISTENTE A:

- Salpicaduras durante la aplicación
- Suciedad y manchas caseras
- Lavados ligeros (ver Instrucciones Para Lavado)

CARACTERÍSTICAS:

- Calidad excelente
- Ocultamiento excelente
- Fácil de aplicar
- Poco olor
- Acabado elegante y mate

APPLICATION:

WHERE TO USE: Duron Plastic Kote Interior Acrylic Latex Flat is for use on properly prepared interior drywall, plaster, masonry and incidental wood surfaces. This is Duron's most durable and washable interior flat wall paint. It offers good resistance to burnishing when it is properly washed. This product is **NOT** recommended for high moisture areas, as a trim paint, or for use on high traffic areas where frequent, hard washings are usually required [higher sheen or enamel finishes are recommended for these areas].

* **SURFACE PREPARATION:** All surfaces must be dry, clean and free of defects. Remove dirt, grease, wallcovering and paste, loose paint and any other surface contamination. Glossy surfaces should be sanded. Fill cracks or depressions with appropriate patching material. Prime with an appropriate Duron primer as recommended below.

* **WARNING!** Some residential, industrial and traffic paint products manufactured before 1978, and some industrial and traffic coatings manufactured thereafter, may contain lead. Disturbing these older paint films by scraping, sanding, burning or other means may create dust particles or fumes which contain lead, a hazardous substance. For information on lead, and proper lead paint removal methods, call the National Lead Information Center at 1-800-LEAD-FYI (or 1-800-532-3394), or the Occupational Safety and Health Administration (OSHA) within the state or jurisdiction in which your project is located. Additional information can be obtained from the Department of the Environment in each state. **BREATHING OR EATING LEAD-CONTAINING VAPOR, DUST OR DEBRIS CAN CAUSE HEALTH PROBLEMS, ESPECIALLY IN CHILDREN OR PREGNANT WOMEN.**

PRIMING:

NEW OR UNPAINTED SURFACES:

- **Non-Staining Wood:** Duron Acrylic Enamel Undercoater or Duron Wall Kote Interior Alkyd Enamel Undercoater.
- **Staining Wood and "Finger-Jointed" Milled Lumber:** Duron Wall Kote Interior Alkyd Enamel Undercoater.
- **Unpainted Drywall:** Duron Ultra Deluxe Interior Drywall Vinyl Primer Sealer.
- **Unpainted Masonry:** Allow new masonry to age 60 days. Duron Acrylic Enamel Undercoater.
- **Concrete Block:** Allow new masonry to age 60 days. Duron Black Kote Latex Block Filler.
- **Galvanized Metal:** Duron Dura Clad Acrylic Galvanized Metal Primer.
- **Ferrous Metal:** Duron Dura Clad (alkyd) Metal Primer.
- **Unpainted Plaster:** Allow new plaster to age 30 days. Duron Acrylic Enamel Undercoater.
- **Unpainted Spackle Patched Areas:** Duron Acrylic Enamel Undercoater.

PREVIOUSLY PAINTED SURFACES (properly prepared):

- **Glossy Finish:** Duron Wall Kote Interior Alkyd Enamel Undercoater.
- **Surfaces Previously Covered with Wallpaper:** Duron Wall Kote Interior Alkyd Enamel Undercoater.

APPLICATION: Stir thoroughly before using. Intermix multiple containers of custom tinted colors as a slight color difference may occur from container to container. Save intermixed material for touch up. Apply with a high quality synthetic brush, roller or sprayer. **See APPLICATION PRECAUTIONS on reverse side.**

APLICACIÓN:

DÓNDE USARLA: Duron Plastic Kote Interior Acrylic Latex Flat es usado en paredes interiores de yeso, mampostería, y superficies incidentales de madera apropiadamente preparadas. Esta pintura interior mate es el producto más durable y lavable de Duron. Esta pintura presenta buena resistencia a descolorarse cuando es adecuadamente lavada. **NO** se recomienda para pintar áreas muy húmedas, molduras o lugares de mucho tráfico que suelen requerir limpiezas fuertes y frecuentes (para estas cosas se recomienda usar acabados de esmalte brillantes).

* **PREPARACIÓN DE LA SUPERFICIE:** Todas las superficies deben estar secas, limpias y sin defectos. Quite la basura, grasa, papel de tapizar y pasta, pintura suelta y cualquier otro contaminante de las paredes. Las superficies brillantes se deben lijar. Cubra las rajaduras o depresiones con material de relleno adecuado. Aplique una pintura de fondo apropiada que le recomiende más abajo.

* **ADVERTENCIA!** Algunos productos de pinturas para uso residencial, industrial y zonas de tráfico fabricados antes de 1978, y algunos revestimientos industriales y para zonas de tráfico fabricados después de ese año, pueden contener plomo. Al quitar estas pinturas viejas raspándolas, lijándolas, quemándolas o por otros medios, se pueden crear partículas de polvo o gases que contienen plomo, una sustancia nociva. Para obtener información sobre el plomo y los métodos apropiados para quitar pintura con base de plomo, llame al Centro Nacional de Información sobre Plomo al 1-800-LEAD-FYI (o 1-800-532-3394), o a la Administración de Seguridad y Salud Ocupacional (OSHA) en el estado o jurisdicción en que se encuentre su proyecto. Puede obtener más información en el Departamento de Medio Ambiente de cada estado. **LA INHALACIÓN O INGESTIÓN DE VAPORES, POLVO O RESIDUOS QUE CONTENGAN PLOMO PUEDE OCASIONAR PROBLEMAS DE SALUD, ESPECIALMENTE EN NIÑOS O MUJERES EMBARAZADAS.**

IMPRIMACIÓN:

SUPERFICIES NUEVAS O SIN PINTAR:

- **Madera no barnizable:** Imprimador de esmalte acrílico Duron o Imprimador de esmalte alquídico para interiores Duron Wall Kote.
- **Madera barnizable y madera empalmada:** Imprimador de esmalte alquídico para interiores Duron Wall Kote.
- **Pared de cartón de yeso sin pintar:** Sellador imprimador de vinilo Duron Ultra Deluxe para paredes interiores de cartón de yeso.
- **Mampostería sin pintar:** Deje secar 60 días la mampostería nueva. Imprimador de esmalte acrílico Duron.
- **Bloques de hormigón:** Deje secar 60 días las obras nuevas. Relleno de látex Duron Black Kote para bloques.
- **Metal galvanizado:** Imprimador de orlicilo para metal galvanizado Duron Dura Clad.
- **Metal de hierro:** Imprimador (alquídico) de metal Duron Dura Clad.
- **Enlucido sin pintar:** Deje secar 30 días el enlucido nuevo. Imprimador de esmalte Duron Acrylic.
- **Áreas parchadas sin pintar:** Imprimador de esmalte Duron Acrylic.
- **SUPERFICIES PREVIAMENTE PINTADAS (debidamente preparadas):**
- **Acabado brillante:** Imprimador de esmalte alquídico para interiores Duron Wall Kote.
- **Superficies anteriormente tapizadas con papel:** Imprimador de esmalte alquídico para interiores Duron Wall Kote.

APLICACIÓN: Revuélvelo bien la pintura antes de usarla. Cuando tenga varios envases de pintura de color preparado de encargo, combínelos todos, pues puede haber una ligera diferencia de tono entre uno y otro. Guarde pintura ya combinada para retoques. Aplique la pintura con una brocha sintética, rodillo o rodador de pistola de buena calidad. **Vea PRECAUCIONES PARA LA APLICACIÓN en el reverso.**

COLOR AVAILABILITY: One Coat White, ready-mixed colors and custom tint bases (White Base, Midtone Base, Deep Base, Accent Base and Neutral Base). See your Duron sales representative for details regarding availability of "special" ready-mixed colors.

NOTE: More than one coat over a "white" color primer may be required with finish colors in the yellow, pink, orange/peach or red color families, and finish colors made in the Neutral Base.

WASHING INSTRUCTIONS: Wait 1 month after application, then remove most dirt by washing with a large sponge, lukewarm water and a mild detergent using light to moderate hand pressure. Rinse with clean water. To remove grease or stains, rub with a soft cloth dampened with mineral spirits then wash as above.

NOTE: All flat paints tend to burnish or "gloss up" and hence appear discolored if too much pressure is applied during washing. This is especially apparent in darker colors.

APPLICATION PRECAUTIONS:

Do not add paint additives, mineral spirits or other solvents to this paint. Do not apply when the surface or air temperature is below 50°F. Do not expose to freezing temperatures in storage.

GENERAL CAUTIONS:

- 1) DO NOT TAKE INTERNALLY.
- 2) KEEP OUT OF REACH OF CHILDREN.
- 3) 24 HOUR EMERGENCY NUMBER:
1-800-228-5635, EXT. 014
OUTSIDE U.S.A., CALL 612-221-3999, EXT. 014
- 4) PROTECT PRODUCT FROM FREEZING.
- 5) USE ONLY AT TEMPERATURES ABOVE 50°F.
- 6) ALWAYS FOLLOW THE LABEL CAUTIONS.
SEE THE MATERIAL SAFETY DATA SHEET (MSDS)
FOR ADDITIONAL SAFETY INFORMATION.

TECHNICAL DATA:

ITEM NUMBER: 17-series

TINTING: Custom Tint Bases Only, with Duron Universal Colorants

VEHICLE TYPE: Acrylic Latex Emulsion

* **AVERAGE WEIGHT PER GALLON:** 12.3 lbs.

* **VISCOSITY:** 90 - 95 Krebs Units

GLOSS: Not applicable

SHEEN: 1.5 - 2.5%

FLASH POINT: Non-Flammable

HEAT RESISTANCE: Intermittent up to 150°F.

RECOMMENDED COVERAGE: Smooth surfaces: 400 sq. ft. per gallon. On rough surfaces coverage will be reduced

WET FILM THICKNESS: 4.0 mils @ 400 sq. ft.

* **DRY FILM THICKNESS:** 1.5 mils @ 400 sq. ft.

* **% SOLIDS BY VOLUME:** 38 ± 2%

* **% SOLIDS BY WEIGHT:** 58 ± 2%

DRYING TIME: (77°F.-50% R.H.)

A. TO TOUCH: 30 minutes

B. TACK FREE: 2 hours

C. RECOAT: 4 hours

NOTE: Drying time may be extended with variations in temperature and/or humidity.

REDUCTION SOLVENT:

A. BRUSH & ROLLER: Clean water; up to 4 ounces per gallon.

B. SPRAY: Clean water; up to 8 ounces per gallon.

CLEAN UP: Soap and water.

* Based on colors made in White Base.

VOC/VOS: This product series contains less than 2.09 pounds of VOC(VOS) per gallon (250 grams per liter) of coating.

COLORES DISPONIBLES: One Coat White, colores ya mezclados y bases de tinte de encargo (White Base, Midtone Base, Deep Base, Accent Base and Neutral Base). Vea a su Representante de Ventas Duron para obtener detalles sobre colores «especiales» ya mezclados.

NOTA: Con colores de las familias del amarillo, rosado, naranja/durazno o rojo, así como con colores hechos con la Neutral Base, quizás haya que aplicar más de una capa sobre un imprimador color "blanco."

INSTRUCCIONES COMO LAVARSE: Esperar 1 mes después de aplicar la pintura; luego quite la mayor parte de la suciedad lavando la superficie pintada con una esponja grande, agua tibia y un detergente suave aplicando presión moderada con sus manos. Enjuague con agua limpia. Para quitar grasa o manchas, frote la superficie pintada con una tela suave humedecida con alcohol mineral y luego lava en la forma indicada.

NOTE: Todas las pinturas mate tienden a quemarse o parecen descolorarse si demasiada presión es aplicada durante el lavado. Esto es especialmente aparente en los colores oscuros.

PRECAUCIONES PARA LA APLICACIÓN: No añada alcoholes minerales, aditivos u otros disolventes a esta pintura. No la aplique cuando la temperatura ambiente o de la superficie sea inferior a 50°F. No la exponga a temperaturas de congelación cuando esté almacenada.

PRECAUCIONES GENERALES:

- 1) NO INGERIA ESTE PRODUCTO.
- 2) MANTENGASE FUERA DEL ALCANCE DE LOS NIÑOS.
- 3) PARA INFORMACIÓN MEDICA DE EMERGENCIA LAS 24 HORAS, LLAME AL 1-800-228-5635, EXTENSIÓN 014 DESDE FUERA DE E.A.U., LLAME AL 612-221-3999, EXTENSIÓN 014.
- 4) NO DEJE CONGELAR ESTE PRODUCTO.
- 5) USESE ÚNICAMENTE A TEMPERATURAS SUPERIORES A 50°F.
- 6) SIGA SIEMPRE LAS PRECAUCIONES INDICADAS EN LA ETIQUETA.
VEA MÁS INFORMACIÓN SOBRE SEGURIDAD EN LA HOJA DE DATOS SOBRE SEGURIDAD DE LOS MATERIALES (MSDS).

DATOS TÉCNICOS:

NÚMERO DE ARTÍCULO: Serie 17

TINTE: Bases de tinte de encargo, únicamente con colorantes universales Duron

TIPO DE VEHÍCULO: Emulsión de acrílica de látex

* **PESO PROMEDIO POR GALÓN:** 12.3 lbs.

* **VISCOSIDAD:** 90 - 95 unidades Krebs

BRILLO: No se aplica

REPLANDOR: 1.5 - 2.5%

PUNTO DE INFLAMABILIDAD: No inflamable

RESISTENCIA TÉRMICA: Intermittente hasta 150°F

COBERTURA RECOMENDADA: Superficies lisas: 400 pies²/galón. En superficies ásperas disminuye la cobertura.

ESPOSOR HUMEDA EN MILESÍMAS: 4.0 milésimas por 400 pies²

* **ESPOSOR FILME HUMEDO:** 1.5 milésimas por 400 pies²

* **% DE SÓLIDOS POR VOLUMEN:** 38 ± 2%

* **% DE SÓLIDOS POR PESO:** 58 ± 2%

TIEMPO DE SECADO: (77°F.- 50% humedad relativa)

A. AL TACTO: 30 minutos

B. SIN PEGARSE: 2 horas

C. PARA LA SEGUNDA MANO: 4 horas

NOTA: El tiempo de secado puede prolongarse cuando hay variaciones de temperatura y/o humedad.

SOLVENTE REDUCTOR:

A. BROCHA Y RODILLO: Agua limpia; hasta 4 onzas por galón.

B. PISTOLA ROCIADORA: Agua limpia; hasta 8 onzas por galón.

LIMPIEZA: Jabón y agua.

* Basado en el color Base Blanco (White Base).

COV/SOV: Este producto contiene menos de 2.09 libras de compuestos orgánicos volátiles (COV) [solvente orgánico volátil (SOV)] por galón (250 gramos por litro) de revestimiento.

1. Product And Company Identification
Supplier

Duron, Inc.
 10406 Tucker Street
 Beltsville, MD 20705-2297

Company Contact: Environmental Service
 Telephone Number: (301)902-3288
 FAX Number: (301)595-0401
 Web Site: Duron.com

Manufacturer

Duron, Inc.
 10406 Tucker Street
 Beltsville, MD 20705-2297

Company Contact: Environmental Service
 Telephone Number: (301)902-3288
 FAX Number: (301)595-0401
 Web Site: Duron.com

Supplier Emergency Contacts & Phone Number

PROSAR Product Safety: (800) 228-5635
 CHEMTREC: 800-424-9300

Manufacturer Emergency Contacts & Phone Number

PROSAR Product Safety: 800.228.5635 EXT014
 CHEMTREC: 800-424-9300

Issue Date: 07/26/2000

Product Name: IMPRESSIONS PLUS LOW SPATTER INTERIOR LATEX FLAT WALL PAINT WHITE
 CAS Number: Not Established
 Chemical Family: INTERIOR LATEX FLAT PAINT
 MSDS Number: 563
 Product Code: 88-LINE

Synonyms

88-911 WHITE 88-919 Antique White 88-918 Bone White 88-917 Shell White

2. Composition/Information On Ingredients

Ingredient Name	CAS Number		Percent Of Total Weight
CALCIUM CARBONATE	1317-65-3	<	26.5
DIATOMACEOUS EARTH, FLUX-CALCINED	68855-54-9		6
ETHYLENE GLYCOL	107-21-1	<	1.2
KAOLIN	1332-58-7	<	18.7
Polyvinyl Acetate Resin	24937-78-8		6.6
SILICA, CRISTOBALITE	14464-46-1	<	2.5
TITANIUM DIOXIDE	13463-67-7	<	7
VINYL ACRYLIC RESIN	25076-01-1		5.7
WATER	7732-18-5	<	47.9

3. Hazards Identification
Eye Hazards

Trace amounts of amine and residual monomer vapors may be irritating to the eyes especially in poorly ventilated areas. Irritation in the form of redness, tearing and/or blurred vision. EYE CONTACT: Vapors can cause severe conjunctivitis.

Skin Hazards

due to individual sensitization, this product can cause skin irritation upon prolonged or repeated contact.

Ingestion Hazards

Can cause gastrointestinal irritation, nausea, vomiting and diarrhea. Aspiration of material into lungs can cause

3. Hazards Identification - Continued

Ingestion Hazards - Continued

chemical pneumonitis which can be fatal.

ETHYLENE GLYCOL: CAS #107-21-1 TOXIC DATA: INGESTION: Slightly toxic to humans (oral LD: 1.6 g/kg). Causes mental sluggishness followed by difficulty in breathing and heart failure, kidney and brain damage, possibly death. Practically non-toxic to animals (or LD50 rats= 8.5 g/kg).

Inhalation Hazards

Excessive inhalation of vapors can cause nasal and respiratory irritation, dizziness, weakness, fatigue, nausea and/or headache. Overexposure can cause neurological damage.

INHALATION: Mists or vapors from hot operations, can cause mental sluggishness pulmonary edema (accumulation of fluid in the lungs, signs and symptoms can be delayed for several hours) and bronchial pneumonia.

4. First Aid Measures

Eye

If this product comes in contact with the eyes, flush with large quantities of water for at least 15 minutes, lifting upper and lower lids occasionally.

Skin

Thoroughly wash exposed area with soap and large quantities of water for at least 15 minutes. Remove contaminated clothing. Launder contaminated clothing before reuse.

Ingestion

Drink 1 or 2 glasses of water to dilute. DO NOT INDUCE VOMITING. Consult a physician or poison control center immediately. Treat symptomatically.

Inhalation

Individual may experience dizziness or lightheadedness when working in areas of high vapor concentrations. Victim should seek air free of vapors. If breathing stops, begin artificial respiration and seek immediate medical attention.

5. Fire Fighting Measures

Flash Point: NA °F NA °C

Flammability Class: IIIB

Fire And Explosion Hazards

Never use a welding or cutting torch on or near container (even empty) because residue may ignite.

Extinguishing Media

Class B extinguisher. Use foam, carbon dioxide or dry chemical fire fighting apparatus.

Fire Fighting Instructions

The use of self-contained breathing apparatus is recommended for fire fighters. Water may be unsuitable as an extinguishing media, but helpful in keeping adjacent containers cool. Avoid spreading burning liquid with water used for cooling.

6. Accidental Release Measures

Eliminate all ignition sources (flares, flames including pilot lights, electrical sparks). Recover free product. Add sand, earth or other suitable absorbent to spill area. Minimize skin contact. Ventilate confined spaces. Keep product out of sewers and watercourses by diking or impounding. Assure conformity with applicable governmental regulations. Continue to observe precautions for volatile, combustible vapors from absorbed material.

7. Handling And Storage

No Data Available...

IMPRESSIONS PLUS LOW SPATTER INTERIOR LATEX FLAT WALL PAINT WHITE**7. Handling And Storage - Continued****Handling And Storage Precautions**

KEEP FROM FREEZING.

KEEP OUT OF THE REACH OF CHILDREN.

Work/Hygienic Practices

DO NOT eat, drink or smoke while using this product. Thoroughly wash hands before eating or smoking.

8. Exposure Controls/Personal Protection**Engineering Controls**

Provide sufficient mechanical (general) and/or local exhaust ventilation to maintain exposure below TLV.

Eye/Face Protection

Safety glasses, chemical goggles and/or face shields are recommended to safeguard against potential eye contact.

Skin Protection

Chemical resistant plastic or rubber gloves.

Respiratory Protection

The use of respiratory protection depends on vapor concentration above the time weighted TLV: use NIOSH/MSHA approved respirator.

Ingredient(s) - Exposure Limits

ETHYLENE GLYCOL

ACGIH TLV-CEILING 100 mg/m3

KAOLIN

ACGIH TLV-TWA 2 mg/m3

OSHA PEL-TWA 15 mg/m3

OSHA PEL-TWA 5 mg/m3

Polyvinyl Acetate Resin

Not Established

SILICA, CRISTOBALITE

ACGIH TLV-TWA 0.05 mg/m3

OSHA PEL-TWA 250/%SiO₂+5 mppcfOSHA PEL-TWA 30/%SiO₂+2 mg/m3OSHA PEL-TWA 10/%SiO₂+2 mg/m3

TITANIUM DIOXIDE

ACGIH TLV-TWA 10 mg/m3

OSHA PEL-TWA 15 mg/m3

VINYL ACRYLIC RESIN

Not Established

WATER

Not Established

9. Physical And Chemical Properties**Appearance**

Viscous liquid

Odor

Mild odor

Chemical Type: Mixture

Physical State: Liquid

Boiling Point: 212 °F 100 °C

IMPRESSIONS PLUS LOW SPATTER INTERIOR LATEX FLAT WALL PAINT WHITE**9. Physical And Chemical Properties - Continued****Odor - Continued**

pH Factor: 7.5

Solubility: INFINITELY

Evaporation Rate: SLOWER THAN ETHER

OFF Whites Specific Gravity = 1.43 %Non Volatile Volume = 66.8%

VOLATILE ORGANIC CONTENT: 0.52 POUNDS/GALLON (62 GRAMS/LITER)

White Specific Gravity = 1.38 % Non Volatile Volume = 70%

VOC= 0.49 Pounds/ Gallon (59 Grams/Liter)

10. Stability And Reactivity

Stability: STABLE

Hazardous Polymerization: WILL NOT OCCUR

11. Toxicological Information**Chronic/Carcinogenicity**

This product contains Crystalline Silica (CS) which is considered a hazard by inhalation. The International Association for Research on Cancer (IARC) has classified CS as carcinogenic for humans (Class 1). CS can also cause silicosis, a non-cancerous lung disease. CS has not been classified as a carcinogen by OSHA or NTP.

Pigment dust would not normally be encountered when handling a packaged paint product containing pre-wetted pigment. Proper respiratory protection should be worn when sanding a dried paint film due to the presence of CS.

Conditions Aggravated By Exposure

Effects of repeated overexposure. No evidence of adverse effects from available information. NOTICE: Reports have associated repeated and prolonged occupational overexposures to solvents with permanent brain and nervous system damage. Intentional misuse by deliberately concentrating and inhaling contents may be harmful or fatal.

Ingredient(s) - Carcinogenicity

SILICA, CRISTOBALITE

NTP - Listed On The National Toxicology Program

Listed In The IARC Monographs

12. Ecological Information

No Data Available...

13. Disposal Considerations

Dispose of product in accordance with applicable local, county, state and federal regulations.

14. Transport Information**Proper Shipping Name**

WATER BASED MATERIAL - KEEP FROM FREEZING

DOT Shipping Label

NONE

This product is not currently regulated under DOT.

The term "WATER BASED MATERIAL - KEEP FROM FREEZING "is used as a measure of count for inventory and shipping purposes.

15. Regulatory Information

No Data Available...

M A T E R I A L S A F E T Y D A T A S H E E T

IMPRESSIONS PLUS LOW SPATTER INTERIOR LATEX FLAT WALL PAINT WHITE

15. Regulatory Information - Continued

SARA Hazard Classes

Acute Health Hazard

Ingredient(s) - U.S. Regulatory Information

ETHYLENE GLYCOL

SARA Title III - Section 313 Form "R"/TRI Reportable Chemical

SARA - Acute Health Hazard

SARA - Chronic Health Hazard

Ingredient(s) - State Regulations

DIATOMACEOUS EARTH, FLUX-CALCINED

New Jersey - Workplace Hazard

ETHYLENE GLYCOL

New Jersey - Workplace Hazard

New Jersey - Environmental Hazard

Pennsylvania - Workplace Hazard

Massachusetts - Hazardous Substance

New York City - Hazardous Substance

KAOLIN

Pennsylvania - Workplace Hazard

SILICA, CRISTOBALITE

New Jersey - Workplace Hazard

Pennsylvania - Workplace Hazard

Massachusetts - Hazardous Substance

TITANIUM DIOXIDE

New Jersey - Workplace Hazard

Pennsylvania - Workplace Hazard

New York City - Hazardous Substance

16. Other Information

Reference Documentation

TITANIUM DIOXIDE: In an inhalation study, E.I. DuPont's Haskel Toxicology Laboratory found evidence of lung cancer (malignant tumors) in 1 out of 77 male rats and 13 out of 74 female rats after they were exposed to 250 mg/m3 titanium dioxide respirable dust for a two year period. The exposure level of 250 mg/m3 is approximately 50 times that permitted in an occupational environment.

The National Cancer Institute (NCI) conducted a feeding study in rats and mice in which either 25,000 or 50,000 parts per million titanium dioxide was given in their diets for two years. Under the conditions of the NCI test, titanium dioxide didn't cause cancer by the oral route.

Disclaimer

All information, recommendations and suggestions appearing herein concerning our product are based upon tests and data believed to be reliable. However, it is the user's responsibility to determine the safety, toxicity and suitability for his own use of the product described herein. Since the actual use by others is beyond our control, no guarantee, expressed or implied, is made by Duron, Inc. as to the effect of such use, the results to be obtained, or the safety and toxicity of the product nor does Duron Inc. assume any liability arising out of use, by others, of the product referred to herein. The information herein is not to be construed as absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations.

DURON, Inc.

Material Safety Data Sheet

RICH LUX WAL-SHIELD LATEX FLAT (041 LINE)

Manufacturer:
M. A. Brudner & Sons, Inc.
600 Reed Road
Broomall, PA 19008

Products and Group Number

041150 (I)	041189 (VI)	041502 (III)	041844 (VI)
041160 (I)	041194 (IV)	041617 (I)	041914 (II)
041181 (III)	041197 (V)	041805 (III)	

Emergen
Working t
Other Ho

FIRE AND EXPLOSION HAZARD DATA

Extinguishing Media: Dry Chemical or Foam
Special Fire Fighting Procedures: Non-Flammable Water may be used to cool and protect exposed containers
Unusual Fire and Explosion Hazards Closed containers may burst if exposed to extreme heat or fire.

REACTIVITY DATA

Stability: Stable
Incompatibility - Materials to avoid: Oxidizers, Acids, Bases
Conditions to Avoid: Elevated temperatures. Contact with
Hazardous Decomposition Products: If involved in fire (for
could conceivably result in release of carbon dioxide and
monoxide
Hazardous Polymerization: Will not occur

HEALTH HAZARD DATA

Primary Route(s) of Exposure: Inhalation, Skin Contact

Effects of Overexposure:

Inhalation: Irritation of respiratory tract. Prolonged inhalation may lead to mucous membrane irritation, drowsiness, and/or light headedness, headache, nausea
Skin Contact: Irritation of skin. Prolonged or repeated contact can cause dermatitis
Eye Contact: Irritation of eyes. Prolonged or repeated contact can create blurred vision, corneal injury
Ingestion: Amounts ingested incidental to consumer and industrial handling are not likely to cause injury, however, ingestion of larger amounts could cause serious injury.

Emergency and First Aid Procedures:

Inhalation: Remove to fresh air. Restore and support continued breathing. Have trained person give oxygen if necessary. Get emergency medical attention
Skin Contact: Wash off quickly with plenty of water, then soap and water. Remove contaminated clothing. Wash contaminated clothing before reuse
Eye Contact: Flush immediately with large amounts of water, especially under lids, for at least 15 minutes. Obtain emergency medical treatment
Ingestion: If swallowed, obtain medical treatment immediately

SPILL OR LEAK PROCEDURES

Steps to be taken in case material is released or spilled:
Contain for disposal according to health and environmental regulations
Clean up with water before allowing to dry
Waste Disposal Method: Dispose in accordance with local regulations.

SPECIAL PROTECTION INFORMATION

Respiratory protection: Control environmental concentration applicable standards. Where respiratory protection is required, NIOSH/MSHA approved respirators in accordance with OSHA 29 CFR 1910.134
Ventilation: Maintain adequate ventilation to ensure air entry application and drying to prevent build up of vapors
Personal Protective Equipment: Eye Wash, Safety Shower, or goggles, Impervious Gloves, Skin Cream (if needed)

SPECIAL PRECAUTIONS

Handling and Storage: Store below 100 degree F. Keep fire
Other Precautions: Do not take internally. Keep out of reach

The above information concerns this product as currently formulated and is based on information available at this time. The addition of thinners, reducers or other additives to this product may substantially alter the composition and hazards of the product. Since conditions of use are beyond our control, we make no warranties, express or implied, and assume no liability in connection with any use of this information

RICH LUX WAL-SHIELD LATEX FLAT (041 LINE)

Ingredients (Percent by Weight)

Group Number (See Front Page)		CAS No	I	II	III	IV	V	VI	LEL %	VP	Exposure Limit	
Ingredients			Wt %	Wt %	Wt %	Wt %	Wt %	Wt %			TLV/TWA	TLV/STEL
Hazardous												
Titanium Dioxide		13463-67-7	11-30	0	11-30	1-10	1-10	11-30	N/A	N/A	10 mg/m ³ (1)	N/E
Calcium Carbonate		1317-65-3	0	11-30	0	11-30	0	1-10	N/A	N/A	10 mg/m ³ (1)	N/E
Anhydrous Aluminum Silicate		1332-58-7	11-30	0	11-30	0	11-30	11-30	N/A	N/A	10 mg/m ³ (1)	N/E
Diatomaceous Earth		68855-54-9	1-10	1-10	1-10	1-10	1-10	1-10	N/A	N/A	10 mg/m ³ (1)	N/E
Silica		14808-60-7	1-10	1-10	1-10	1-10	1-10	1-10	N/A	N/A	0.1 mg/m ³ (2)	N/E
Trimethylpentanediol isobutyrate (Texanol)		25265-77-4	1-10	0	1-10	0	1-10	1-10	0.62	1.0	N/E	N/E
Propylene Glycol		57-55-6	1-10	0	0	1-10	1-10	0	2.6	0.22	N/E	N/E
Ethylene Glycol		107-21-1	0	1-10	1-10	0	0	1-10	3.2	0.1	50 ppm (3)	N/E
Non Hazardous												
Water		7732-18-5	>3	>3	>3	>3	>3	>3				
Vinyl Acetate Acrylic Copolymer		25067-01-0	>3	>3	>3	>3	>3	>3				
Styrene-Acrylic Copolymer		Proprietary	>3	0	>3	0	>3	>3				
Black Iron Oxide		1317-61-9	0	>3	0	0	0	0				

Not Applicable

Physical
Rolling Fire
Weight per
Percent Vol
Evaporable
Flash Point
Flash Point
Flammable
Flammable
DOT - N

CAS No - Chemical Abstract Number
LEL%-Lower Exposure Limit
VP-Vapor Pressure (mm Hg at 25°C)
TLV/TWA-Threshold Limit Value/Time Weighted Average
TLV/STEL-Threshold Limit Value/Short Term Exposure Limit
OSHA/PEL-Occupational Safety Health Administration/Permissible Exposure Limit
1-Dust hazard does not apply to liquid paint
2-Respirable Dust
3-Ceiling Limit
N/A-Not applicable
N/E-Not established

PRODUCT INFORMATION

B-I-N® Bulletin 091S (2/96)

- Seals new wood, wallboard, cured plaster, all porous surfaces
- Adheres to hard-to-stick to materials - gloss paint, Masonite®, glass, metal
- Blocks out stains - water marks, knots & sap, smoke & soot, graffiti, grease, crayon
- Provides interior vapor barrier
- Dries fast; lets you top coat in 45 minutes

Description

B-I-N Primer Sealer is a fast-drying, Shellac-based white-pigmented undercoat- the original stain-killing primer-sealer. It functions in three ways:

1. Primes white.
2. Seals surfaces to provide a smooth base for the finish coat.
3. Kills stains.

B-I-N dries in just 45 minutes, completely seals porous surfaces, adheres to almost everything and forms a vapor barrier. It insures quality results; saves time and paint. The topcoat goes farther and often only one coat is needed. That's why B-I-N is the premier all-purpose interior primer-sealer.

B-I-N may also be used for many select spot exterior applications such as knots and sappy streaks, rust stains, copper screening stains, puttie nailheads, weathered siding, water marks and trim touch-up.

Color

Available only in white.

Tinting

May be tinted with up to 4 ounces of many "universal" tinting colors per gallon of B-I-N. Check for compatibility. Tinting helps topcoat

B-I-N Product Information

Finish

Dries to an eggshell finish which promotes solid adhesion of the topcoat.

Uses

B-I-N is suitable for all types of interior surfaces. Its shellac base and quick-drying features make it an exceptional sealer for porous surfaces. It is ideal over old or new (but fully cured) plaster walls, drywall, spackled areas, wallpaper, new or previously painted wood and plywood, unpainted furniture, wicker. Because of its unusual adhesion, it is recommended as a primer on dense, hard-to-grip surfaces such as gloss-painted walls and woodwork, metal, Formica®, Masonite®, other hardboard, glass and ceramic tile without sanding. It is unmatched in ability to seal off the widest variety of hard-to-kill stains, including knots and sappy streaks in new wood, graffiti, water stains, crayon, ink, lipstick, stains from grease, smoke, soot and fire damage.

Finishes Recommended for Use Over B-I-N

B-I-N can be used under any type of gloss, semi-gloss or flat interior paint-water-thinned (latex) or solvent-thinned (oil-based). Not recommended for use under polyurethane's, or under special highly alkaline acoustical of flock type coatings generally used for ceilings and for special effects on other surfaces.

Before using B-I-N under any lacquer, test to see whether the lacquer dissolves or softens the B-I-N film.

Spot priming is recommended only under high-hiding paints; primed spots may flash through paints with little hiding strength-e.g., many ceiling paints. If this occurs, paint entire surface with B-I-N before applying paint with poor hiding.

Thinning

Do not thin. Add a small amount of a denatured alcohol only if B-I-N thickens in the can during application because of solvent evaporation.

Surface Preparation

Surface must be clean and dry. Test all old painted or varnished surfaces for adhesion by making an X with a razor or knife and placing a section of Scotch® tape over it, pressing it down firmly. After 30 seconds yank the tape off (do not pull, but yank at the tape). If the old paint or varnish comes off on the tape, the paint should be removed. Remove any wax with mineral spirits or commercial wax remover. Allow to dry thoroughly. Scrape off loose or scaling paint and wallpaper paste. Fill wall cracks and nail holes with patching paste; sand smooth when dry. Sand unfinished wood with fine sandpaper. Remove dust with tack cloth. Remove rust on metal by sanding, then wipe down with mineral spirits or turpentine.

When applying textured ceiling paint in rooms where there has been heavy smoking, check surfaces for brown nicotine stains that rub off or damp cloth. If present, wash clean and let dry. Otherwise, these stains may bleed through the finish paint.

Application Methods

B-I-N may be brushed, rolled or sprayed, using material at container consistency. Brush Application: Flow on freely. B-I-N is self-leveling and dries free from brush ridges. Roller: Use a short nap roller. Sprayer: Use between 20 and 30 pound pressure for air, 0.015 tip for airless. Airless sprayers only: To slow drying and prevent clogging, up to 3 fl. oz., paint thinner or VMP naphtha per gallon B-I-N may be added. Stir vigorously just before use to disperse thoroughly.

Can be applied at temperatures as low as 0°F.

Drying Time

Dry to handle: 15 to 20 minutes. Dry, ready for final finish: 45 minutes. At very low temperatures or high humidity, allow extra drying time.

Coverage by Brush

On non-porous surfaces: up to 500 sq. ft. per gallon (12 sq. m. per liter). On porous surfaces, such as wallboard, up to 450 sq. ft. per gallon (11 sq. m. per liter).

Cleaning Equipment

Clean brush or roller while still wet. Most effective and simple to use is a solution of household ammonia (1 part) and warm water (3 parts). Soak brush or roller thoroughly, well into the bristle or nap; then wash with soap and water and rinse. Or clean with denatured alcohol. Sprayer may be cleaned with ammonia or alcohol. If ammonia is used, rinse with water, then with alcohol to dry parts.

SPECIFIC INTERIOR USES

New Plaster. B-I-N effectively seals off porous plaster walls, permitting, in many cases, the use of only one finish coat. Tinting to approximate shade of finish coat is recommended. Apply over new plaster only after it is thoroughly cured and dry. Industry practice is to wait at least 90 days before painting. Even then, it is wise to have the plaster confirm that the surface is ready for paint.

Drywall. B-I-N seals off gypsum wallboard (sheetrock) effectively, insures uniform holdout of the finish coat of paint on the paper facing as well as on taped joint areas. And it does not raise facing paper fibers.

New Wood and Plywood. On these surfaces, B-I-N performs three functions: (1) Seals the wood for uniform holdout of finish coat of paint. (2) Kills stains from knots or sappy streaks. (3) Seals off spackled or puttied nailheads.

Hard Wallboard. Because of its shellac base, B-I-N® bonds firmly to Masonite and similar dense materials, providing a perfect prime coat for a finish coat. Be sure surface is free of wax and surface agents before priming.

Metal, Glass, Formica®, Ceramic and Plastic Tile. Metal pipes, ductwork and ornamental pieces; glass window and mirrors; and ceramic tile, tile board, plastic sheet and tile baked on metal all present hard, non-porous surfaces to which ordinary primers often won't adhere. But the remarkable adhesion of shellac-based B-I-N provides a "bonding" undercoat that's an excellent base for the finish coat. Sanding or other treatment is not needed for a good bond.

Glossy and Stained Woodwork. B-I-N can be applied to previously painted gloss woodwork with no surface preparation, except wax



MATERIAL SAFETY DATA SHEET

Rohm and Haas Company

RECEIVED
MAR 13 1995
CHEMICALS SE.

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

RHOPLEX® AC-33 Emulsion

Product Code : 65197
Key : 905293-6

MSDS Date : 03/08/95

COMPANY IDENTIFICATION
Rohm and Haas Company
100 Independence Mall West
Philadelphia, PA 19106-2399

EMERGENCY TELEPHONE NUMBERS
HEALTH EMERGENCY : 215-592-3000
SPILL EMERGENCY : 215-592-3000
CHEMTREC : 800-424-9300

RHOPLEX® is a trademark of Rohm and Haas Company or one of its subsidiaries or affiliates.

2. COMPOSITION/INFORMATION ON INGREDIENTS

No.		CAS REG NO.	WEIGHT(%)
1	Acrylic polymer	Not Hazardous	45-48
2	Individual residual monomers	Not Required	< 0.1
3	Aqua ammonia	1336-21-6	0.2 MAX
4	Water	7732-18-5	52-55

See SECTION 7, Handling and Storage.

See SECTION 8, Exposure Controls / Personal Protection

3. HAZARDS IDENTIFICATION

Primary Routes of Exposure

Inhalation
Eye Contact
Skin Contact

Inhalation

Inhalation of vapor or mist can cause the following:
- headache - nausea - irritation of nose, throat, and lungs

Eye Contact

Direct contact with material can cause the following:
- slight irritation

Skin Contact

Prolonged or repeated skin contact can cause the following:
- slight skin irritation

4. FIRST AID MEASURES

Inhalation

Move subject to fresh air.

Eye Contact

Flush eyes with a large amount of water for at least 15 minutes. Consult a physician if irritation persists.

Skin Contact

Wash affected skin areas thoroughly with soap and water. Consult a physician if irritation persists.

Ingestion

If swallowed, give 2 glasses of water to drink. Consult a physician. Never give anything by mouth to an unconscious person.

5. FIRE FIGHTING MEASURES

Flash Point	Noncombustible
Auto-ignition Temperature	Not Applicable
Lower Explosive Limit	Not Applicable
Upper Explosive Limit	Not Applicable

Unusual Hazards

Material can splatter above 100C/212F. Dried product can burn.

Extinguishing Agents

Use extinguishing media appropriate for surrounding fire.

Personal Protective Equipment

Wear self-contained breathing apparatus (pressure-demand MSHA/NIOSH approved or equivalent) and full protective gear.

6. ACCIDENTAL RELEASE MEASURES

Personal Protection

Appropriate protective equipment must be worn when handling a spill of this material. See SECTION 8, Exposure Controls/Personal Protection, for recommendations. If exposed to material during clean-up operations, see SECTION 4, First Aid Measures, for actions to follow.



CONTINUATION Procedures

Keep spectators away. Floor may be slippery; use care to avoid falling. Contain spills immediately with inert materials (e.g. sand, earth). Transfer liquids and solid diking material to separate suitable containers for recovery or disposal.
CAUTION: Keep spills and cleaning runoff out of municipal sewers and open bodies of water.

7. HANDLING AND STORAGE

Storage Conditions

Keep from freezing; material may coagulate. The minimum recommended storage temperature for this material is 1C/34F. The maximum recommended storage temperature for this material is 60C/140F.

Handling Procedures

Monomer vapors can be evolved when material is heated during processing operations. See SECTION 8, Exposure Controls/Personal Protection, for types of ventilation required.

NOTE: Formaldehyde will be generated under acidic conditions. Maintain adequate ventilation under these conditions to prevent exposure to formaldehyde above the Rohm and Haas Co. recommended ceiling of 0.3 ppm.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Limit Information

No.		CAS REG NO.	WEIGHT(%)
1	Acrylic polymer	Not Hazardous	45-48
2	Individual residual monomers	Not Required	< 0.1
3	Aqua ammonia	1336-21-6	0.2 MAX
4	Water	7732-18-5	52-55

Component		ROHM AND HAAS		OSHA		ACGIH	
No.	Units	TWA	STEL	TWA	STEL	TWA	STEL
1		None	None	None	None	None	None
2		a	a	a	a	a	a
3	ppm	25 b	35 b	None	35 b	25 b	35 b
4		None	None	None	None	None	None

- a Not Required
b As Ammonia

Respiratory Protection

A respiratory protection program meeting OSHA 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use. None required if airborne concentrations are maintained below the exposure limit listed in 'Exposure Limit Information'. For airborne concentrations up to 10 times

CONTINUATION

the TWA/TLV's listed in "Exposure Limit Information", wear a MSHA/NIOSH approved (or equivalent) half-mask, air-purifying respirator. Air-purifying respirators should be equipped with an ammonia/methylamine cartridge and dust/mist filters.

Eye Protection

Use chemical splash goggles (ANSI Z87.1 or approved equivalent).

Hand Protection

The glove(s) listed below may provide protection against permeation. Gloves of other chemically resistant materials may not provide adequate protection:
- Neoprene

Engineering Controls (Ventilation)

Use local exhaust ventilation with a minimum capture velocity of 100 ft/min. (0.5 m/sec.) at the point of vapor evolution. Refer to the current edition of Industrial Ventilation: A Manual of Recommended Practice published by the American Conference of Governmental Industrial Hygienists for information on the design, installation, use, and maintenance of exhaust systems.

Other Protective Equipment

Facilities storing or utilizing this material should be equipped with an eyewash facility.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	Milky
Color	White
State	Liquid
Odor Characteristic	Ammonia odor
pH	9.0 to 9.9
Viscosity	7500 CPS Maximum
Specific Gravity (Water = 1)	1.0 to 1.2
Vapor Density (Air = 1)	< 1 Water
Vapor Pressure	17 mm Hg @ 20°C/68°F Water
Melting Point	0°C/32°F Water
Boiling Point	100°C/212°F Water
Solubility in Water	Dilutable
Percent Volatility	52 to 55 % Water
Evaporation Rate (BAC = 1)	< 1 Water

See SECTION 5. Fire Fighting Measures

10. STABILITY AND REACTIVITY

Instability

This material is considered stable. However, avoid temperatures above 177°C/350°F, the onset of polymer decomposition. Thermal decomposition is dependent on time and temperature.



CONTINUATION

Hazardous Decomposition Products

Thermal decomposition may yield acrylic monomers.

Hazardous Polymerization

Product will not undergo polymerization.

Incompatibility

There are no known materials which are incompatible with this product.

11. TOXICOLOGICAL INFORMATION

Acute Data

No toxicity data are available for this material.
The information shown in SECTION 3, Hazards Identification, is based on the toxicity profiles for a number of acrylic emulsions that are compositionally similar to this product. Typical data are:
Oral LD50 - rat: > 5000 mg/kg
Dermal LD50 - rabbit: > 5000 mg/kg
Skin Irritation - rabbit: practically non-irritating
Eye Irritation - rabbit: Inconsequential Irritation

12. ECOLOGICAL INFORMATION

No Applicable Data

13. DISPOSAL CONSIDERATIONS

Procedure

Coagulate the emulsion by the stepwise addition of ferric chloride and lime. Remove the clear supernatant and flush to a chemical sewer. Incinerate liquid and contaminated solids in accordance with local, state, and federal regulations.

14. TRANSPORT INFORMATION

US DOT Hazard Class NONREGULATED

15. REGULATORY INFORMATION

Workplace Classification

This product is considered non-hazardous under the OSHA Hazard Communication Standard (29CFR 1910.1200).

This product is not a 'controlled product' under the Canadian Workplace Hazardous Materials Information System (WHMIS).

CONTINUATION

SARA TITLE 3: Section 311/312 Categorizations (40CFR 370)

This product is not a hazardous chemical under 29CFR 1910.1200, and therefore is not covered by Title III of SARA.

SARA TITLE 3: Section 313 Information (40CFR 372)

This product does not contain a chemical which is listed in Section 313 at or above de minimis concentrations.

CERCLA Information(40CFR 302.4)

Releases of this material to air, land, or water are not reportable to the National Response Center under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or to state and local emergency planning committees under the Superfund Amendments and Reauthorization Act (SARA) Title III Section 304.

Waste Classification

When a decision is made to discard this material as supplied, it does not meet RCRA's characteristic definition of ignitability, corrosivity, or reactivity, and is not listed in 40 CFR 261.33. The toxicity characteristic (TC), however, has not been evaluated by the Toxicity Characteristic Leaching Procedure (TCLP).

United States

All components of this product are in compliance with the Inventory listing requirements of the U.S. Toxic Substances Control Act (TSCA) Chemical Substance Inventory.

Pennsylvania

Any material listed as "Not Hazardous" in the CAS REG NO. column of SECTION 2, Composition/Information On Ingredients, of this MSDS is a trade secret under the provisions of the Pennsylvania Worker and Community Right-to-Know Act.

16. OTHER INFORMATION

Rohm and Haas Hazard Rating		Scale
Toxicity	1	4 = EXTREME
Fire	0	3 = HIGH
Reactivity	0	2 = MODERATE
Special	-	1 = SLIGHT
		0 = INSIGNIFICANT

Ratings are based on Rohm and Haas guidelines, and are intended for internal use.



Rohm and Haas Company
100 Independence Mall West
Philadelphia, PA 19106-2399

PRODUCT: RHOPLEX® AC-33 Emulsion
KEY: 905293-6
DATE: 03/08/95

ABBREVIATIONS:

ACGIH = American Conference of Governmental Industrial Hygienists

OSHA = Occupational Safety and Health Administration

TLV = Threshold Limit Value

PEL = Permissible Exposure Limit

TWA = Time Weighted Average

STEL = Short-Term Exposure Limit

BAC = Butyl acetate

Bar denotes a revision from previous MSDS in this area.

The information contained herein relates only to the specific material identified. Rohm and Haas Company believes that such information is accurate and reliable as of the date of this material safety data sheet, but no representation, guarantee or warranty, express or implied, is made as to the accuracy, reliability, or completeness of the information. Rohm and Haas Company urges persons receiving this information to make their own determination as to the information's suitability and completeness for their particular application.

88,00550308

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing,
Shipbuilding, and Shipcranking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME ACTIVA PRODUCTS, INC.		EMERGENCY TELEPHONE NO. 508 692-9300
ADDRESS (Number, Street, City, State, and ZIP Code) P. O. Box 472, Westford, MA 01885		
CHEMICAL NAME AND SYNONYMS Permastrong		
CHEMICAL FAMILY	FORMULA	
	CaSO₄	1/2H₂O

SECTION II - HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					
HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES				%	TLV (Units)

SECTION III - PHYSICAL DATA

BOILING POINT (°F.)		SPECIFIC GRAVITY (H ₂ O=1)	2.3
VAPOR PRESSURE (mm Hg.)		PERCENT VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR=1)		EVAPORATION RATE (_____=1)	
SOLUBILITY IN WATER	Cold Hot	- 2 - slight	
APPEARANCE AND ODOR	White powder - odorless		

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) Non-flammable o/F Open Flame	FLAMMABLE LIMITS	Exp	Unst
EXTINGUISHING MEDIA	Non-flammable		
SPECIAL FIRE FIGHTING PROCEDURES	None		
UNUSUAL FIRE AND EXPLOSION HAZARDS	None		

SEC. 001 - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE
EFFECTS OF OVEREXPOSURE
Oral ingestion: No effect, eye contact: slight irritat
No ill effects, Skin contact: No effect, Skin absorption - None
EMERGENCY AND FIRST AID PROCEDURES
Eye: Wash with water, Skin: Wash with water, Inhalation: None- Treated
as nuisance dust, Ingestion: None (Industrial Health, Vol. 12, No. 3
Sept. 1983

SECTION VI - REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE		None
INCOMPATIBILITY (Materials to avoid)		None	
HAZARDOUS DECOMPOSITION PRODUCTS		None	
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR		None

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
May be cleaned up with normal housekeeping procedures.
WASTE DISPOSAL METHOD
Any normal disposal method

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type)	
Non-Nuisance dust equipment when conditions demand.	
VENTILATION	LOCAL EXHAUST
	MECHANICAL (General)
SPECIAL	
OTHER	
PROTECTIVE GLOVES	EYE PROTECTION
Not normally necessary	Not normally necessary
OTHER PROTECTIVE EQUIPMENT	

SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING
Store in dry place to prevent setting and bag breakage. No
detrimental health effects.
OTHER PRECAUTIONS
None

8.2 ASTM Tests

Standard Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts¹

This standard is issued under the fixed designation D 344; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method provides for the qualitative and quantitative visual determination of the hiding power of a test paint relative to that of a comparison paint.

1.2 This test method describes only a brushout application procedure in specific detail, but its concepts are valid for other methods of application as well.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards

D16 Terminology Relating to Paint, Varnish, Lacquer, and Related Products²

D1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products³

D1729 Practice for Visual Evaluation of Color Differences of Opaque Materials⁴

D2805 Test Method for Hiding Power of Paints by Reflectometry⁵

E 97 Test Method for Directional Reflectance Factor, 45-deg 0-deg, of Opaque Specimens by Broad-Band Filter Reflectometry⁶

3. Terminology

3.1 Definitions

3.1.1 For definitions of terms used in this test method, refer to Definitions D 16 and the *Paint Coatings Dictionary*.⁷

3.2 Descriptions of Terms Specific to This Standard

3.2.1 *relative hiding power, qualitative*—the characterization of a test paint as being better, equal, or poorer in hiding power than a comparison paint.

3.2.2 *relative hiding power, quantitative*—the spreading rate of a paint expressed as a percent of the spreading rate of

a comparison paint at equal hiding.

4. Summary of Test Method

4.1 *Qualitative*—The test and comparison paints are brushed out uniformly at the same spreading rate on black and white hiding power charts. After drying the brushouts are compared visually to see which paint has been most effective in reducing the substrate contrast.

4.2 *Quantitative*—Additional brushouts are made with the comparison paint, if and as necessary, to determine the spreading rate at which it matches the hiding of the test paint brushout.

5. Significance and Use

5.1 This test method evaluates the hiding power of a test paint relative to a comparison paint. The results have significance only within that relationship. It may be used for production control or quality comparisons.

5.2 When a paint is applied by brush or any other practical method, the opacity of the film is affected by variations in film thickness related to the application procedure and to the application characteristics of the paint. Two paints that hide equally well by this method might therefore differ considerably when applied with a doctor blade, since the latter method gives essentially perfect leveling. Different brushes or surface application conditions can likewise give different results.

Note 1—Test Method D 2805 describes an instrumental method for quantitatively determining hiding power without reference to a material paint standard. The paint film is applied at a uniform thickness (for example, with a doctor blade); the film thickness is measured rigorously, and the opacity is evaluated photometrically. Hiding power is thereby determined with a high degree of precision.

5.3 Test Method D 344 is less precise than Test Method D 2805, but is more practical because it is responsive to the application characteristics of paints and is simpler in concept and execution.

6. Apparatus

6.1 *Balance*, top-loading laboratory balance having a capacity of 100 g and sensitivity of 0.1 g.

6.2 *Syringe*, 10-mL capacity.

6.3 *Paint Brush*, ferrule 2 in. (50 mm) wide and $\frac{1}{16}$ in. (14 mm) thick, tapered polymer filaments $2\frac{1}{2}$ in. (70 mm) long with flagged chisel trim tip.

¹ This test method is under the jurisdiction of ASTM Committee D-01 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.26 on Optical Properties.

Current edition approved May 26, 1989. Published August 1989. Originally published as D 344 - 32. Last previous edition D 344 - 84.

² Annual Book of ASTM Standards, Vol 06.01, 06.02, and 06.03.

³ Annual Book of ASTM Standards, Vol 06.01.

⁴ Annual Book of ASTM Standards, Vol 14.02.

⁵ Annual Book of ASTM Standards, Vol 06.01 and 14.02.

⁶ Published by the Federation of Societies for Coatings Technology, 492 Northtown Rd., Blue Bell, PA 19422.

⁷ Describes the Leneta 2" Parater Certified Standard Paint Brush used by the round-robin participants. Available from Leneta Company, P.O. Box 96, Hockessin, NJ 07032. Equivalent brushes may be used.

6.4 *Container*—A pint can or 250-ml beaker.

6.5 *Test Surface*—A smooth-surfaced paper chart having adjacent black and white areas and coated with a suitable varnish or lacquer so as to render the surface impervious to paint acids. The black and white areas of the chart shall have luminous reflectance factors of 10% maximum and 75% minimum, respectively, when tested in accordance with Test Method E 97. The white areas of the charts used in any one testing program shall not differ in their reflectance factors by more than 1%. Any suitable regular design of contrasting areas may be used. The chart⁸ shall have a defined test area of 0.1 m². Larger test areas may be used if available, with appropriate modification of the indicated calculations.

6.6 *Illumination*, a light source providing diffuse light of reasonable intensity, preferably northern sky light or an approximation of same. (See Practice D 1729).

7. Preparation of Brushouts

7.1 Select a convenient and suitable spreading rate, mutually agreeable to all parties involved in the testing program, and preferably in the range from 400 to 800 ft²/gal (9.8 to 19.6 m²/L). In any case, the spreading rate shall not be so low that the substrate contrast is difficult to see nor so high that it is difficult to apply the paint at a reasonably uniform film thickness.

NOTE 2—The gallon unit referred to here and throughout this test method is the U.S. gallon (3785.4 mL).

7.2 Determine the density D in grams per millilitre of the comparisons and test paints, in accordance with Test Method D 1475.

7.3 Calculate to three significant figures the volume V in millilitres to apply for the selected spreading rate SR as follows:

$$V(\text{mL}) = \frac{100}{SR(\text{m}^2/\text{L})} = \frac{4074.6}{SR(\text{ft}^2/\text{gal})}$$

7.4 Calculate to three significant figures, the weight W in grams corresponding to the volume V (mL) as follows:

$$W(\text{g}) = V(\text{mL}) \times D(\text{g/mL})$$

7.5 To prepare a brushout, first stir the paint well. Then precondition the brush by dipping it into the paint and working it out on a smooth, nonporous surface. Take up the desired volume of paint in the syringe and weigh it with the brush in the empty container. Place the test chart on a level bench top, distribute the paint from the syringe all around onto the test area of the chart, then brush the paint out uniformly within the test area. Set the brushout aside to dry in a horizontal position, protected adequately from dust and under normal room conditions of ventilation and temperature. Reweigh the empty syringe with the brush and container. The loss of weight represents the actual weight of paint applied to the test surface as opposed to the intended weight calculated from 7.3 and 7.4. If there is a discrepancy do not attempt to correct it by removing or applying paint

since this would disturb the leveling of the brushout. Instead calculate the actual spreading rate as follows:

$$SR_A = \frac{W}{A} \times SR_B$$

where

SR_A = actual spreading rate

B = intended weight

A = actual weight, and

SR_B = intended spreading rate

8. Evaluation Procedure

8.1 *Viewing conditions*—When the test and comparison paint brushouts are thoroughly dry, place them vertically side by side against a flat surface and view them from a distance of 5 to 10 ft (1.5 to 3 m) under illumination conditions as described in 6.6.

8.2 Qualitative Evaluation

8.2.1 If the contrast between the black and white areas of the test paint brushout is adjudged less than, equal to, or more than that of the comparison paint brushout, then the hiding power of the test paint is considered as better than, equal to, or poorer than that of the comparison paint.

8.2.2 If the actual spreading rate of the lower contrast paint-out is lower than that of the other paint-out by more than 3%, prepare a second brushout with either paint so as to eliminate the difference, then compare again to confirm or revise the previous estimation of relative hiding power.

8.3 Quantitative Evaluation

8.3.1 If the hiding of the test paint brushout does not match that of the comparison paint at the same spreading rate, make a series of additional comparison paint brushouts at several other spreading rates, differing in steps of approximately 15% and providing contrasts above and below that of the test paint brushout. Refer to these and to the original comparison paint brushout as standards. If the standards are prepared correctly each increase in spreading rate will correspond to a perceptible increase in contrast. Compare the standards under the viewing conditions described in 8.1 to assure that this is the case.

8.3.2 Compare the brushout of the test paint with the standards under the specified viewing conditions to determine which standard it matches in contrast or, if none, to which pair of successive standards it is intermediate. In the latter case view the test paint brushout with the two standards on either side and rate the contrast of the test paint brushout by estimating the contrast difference between it and the lower spreading rate (lower contrast) standard, as a fraction of the contrast difference between the two standards to the nearest fourth. Keeping the test paint brushout in the middle, reverse the position of the two standards and rate the test paint brushout again in the same way. The final rating is the mean of the two to the nearest eighth.

8.3.3 Calculate the spreading rate (SR_C) of the comparison paint at which it is estimated to match the hiding of the test paint brushout as follows:

$$SR_C = SR_1 + V(SR_2 - SR_1)$$

where:

SR_1 = spreading rate of the lower spreading rate (lower contrast) standard.

⁸ Suitable charts are available from Leneta Company, P. O. Box 46, Hokeness, NJ 07423.

SR_c = spreading rate of the higher spreading rate (higher contrast) standard, and

λ = fractional contrast rating of the test paint brushout.

8.3.4 Calculate the relative hiding power of the test paint in accordance with the definition in 3.2.2 as follows:

$$HP_t = \frac{SR_t}{SR_c} \times 100$$

where:

HP_t = relative hiding power of the test paint,

SR_t = spreading rate of the test paint, and

SR_c = spreading rate of the comparison paint at equal hiding, as determined by an actual match with one of the standards or by estimation between two standards as described in 8.3.2.

9. Report

9.1 *Qualitative* (see 8.2)—Report the relative hiding power of the test paint as better than, equal to, or poorer than the comparison paint. The report may be amplified by such terms as exactly, slightly, moderately, considerably, etc., as may seem appropriate.

9.2 *Quantitative* (see 8.3)—Report the relative hiding power of the test coating to the nearest whole number. This is a purely numerical value. Physical units such as square feet per gallon or square metres per litre are not applicable.

10. Precision

10.1 *Qualitative*—Four test paints were rated versus a comparison paint by three laboratories, twice each by one laboratory and once each by the other two, for a total of 16 trials. There was only one discrepancy, which occurred with a paint that was apparently very similar in hiding power to the comparison paint. These results indicate that the method is effective, but more results would be required to develop an appropriate precision statement. Table 1 gives the results of these tests.

10.2 *Quantitative*—In an interlaboratory study of this

TABLE 1 Round Robin Results of Relative Hiding Power of Four White Paints versus a Comparison White Paint

Method	Paint	Laboratory 1		Laboratory 2	Laboratory 3
		Trial 1	Trial 2	2	3
Qualitative	V1	A	A	A	A
	V2 ^a				
	V3	C	C	C	
	V4	C	C	C	
	V5	A	C	C	
Quantitative	V1	125	117	115	120
	V2 ^a	100	100	100	100
	V3	85	93	52	36
	V4	66	32	60	67
	V5	102	90	83	95

^a Indicates that the test paint hides better than the comparison paint

^b Comparison paint, relative hiding power equals 100

^c Indicates that the test paint hides poorer than the comparison paint

method four coatings were evaluated for hiding power against a fifth coating taken as the standard. In one laboratory each material was tested twice, but only once in the other two laboratories. Statistical analysis of the results revealed that the two results for each coating from the one laboratory were as variable as those from the other two. Consequently, the two results were treated as being individual results and the between-laboratory standard deviation was found to be 10 % with 12 df. Based on this standard deviation, the following criterion should be used for judging the acceptability of results at the 95 % confidence level:

10.2.1 *Reproducibility*—Two single results obtained by operators in different laboratories should be considered suspect if they differ in relative hiding power by more than 32 %.

10.2.2 *Repeatability*—A reasonable estimate of within-laboratory precision could not be obtained because only one laboratory repeated the test. However, the repeatability should be similar to the reproducibility.

11. Keywords

11.1 hiding power; relative hiding; opacity

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser¹

This standard is issued under the fixed designation D 4060; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope

1.1 This test method covers the determination of the resistance of organic coatings to abrasion produced by the Taber Abraser on coatings applied to a plane, rigid surface, such as a metal panel.

1.2 Because of the poor reproducibility of this test method, it should be restricted to testing in only one laboratory when numerical abrasion resistance values are to be used. Interlaboratory agreement is improved significantly when rankings of coatings are used in place of numerical values.

1.3 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- D 823 Test Methods for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels²
- D 968 Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive²
- D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers²
- D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base²
- D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base²
- D 2240 Test Method for Rubber Property—Durometer Hardness³

3. Terminology

3.1 Descriptions of Terms Specific to This Standard

3.1.1 Abrasion resistance can be expressed as one or more of the following terms:

3.1.1.1 *wear index*—1000 times the loss in weight in milligrams per cycle.

3.1.1.2 *weight loss*—the loss in weight in milligrams,

determined at a specified number of cycles.

3.1.3 *wear cycles per mil*—the number of cycles of abrasion required to wear a film through to the substrate per mil of film thickness.

4. Summary of Test Method

4.1 The organic coating is applied at uniform thickness to a plane, rigid panel and, after curing, the surface is abraded by rotating the panel under weighted abrasive wheels.

4.2 Abrasion resistance is calculated as loss in weight at a specified number of abrasion cycles, as loss in weight per cycle, or as number of cycles required to remove a unit amount of coating thickness.

5. Significance and Use

5.1 Coating on substrates can be damaged by abrasion during manufacturing and service. This test method has been useful in evaluating the abrasion resistance of attached coatings. Ratings produced by this test method have correlated well with ratings produced by the falling abrasive values in Test Method D 968.

6. Apparatus

6.1 Taber Abraser.⁴

6.2 *Abrasive Wheels*—Resilient calibrase wheels No. CS-10 or CS-17, as required, shall be used. Because of the slow hardening of the rubber bonding material in this type of wheel, the wheels should not be used after the date marked on them, or one year after their purchase if the wheels are not dated.

NOTE 1—The hardness of the wheels can be checked by Test Method D 2240. An acceptable hardness for both types of wheels is 81 ± 5 units on Shore Durometer A-2 Scale.

NOTE 2—The CS-17 wheels produce a harsher abrasion than the CS-10 wheels.

6.3 *Resurfacing Medium*, an S-11 abrasive disk, used for resurfacing the abrasion wheels.

6.4 *Vacuum Pick-Up Assembly*, consisting of a vacuum unit, a variable transformer suction regulator, a nozzle with bracket attachment, and a connecting hose with adaptor.

7. Test Specimens

7.1 Apply a uniform coating of the material to be tested to a plane, rigid panel. Specimens shall be a disk 4 in. (100 mm) in diameter or a plate 4-in. (100-mm) square with rounded corners and with a 1/4-in. (6.3-mm) hole centrally located on

¹ This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.23 on Physical Properties of Applied Paint Films.

Current edition approved May 25, 1990. Published July 1990. Originally published as D 4060 - 81. Last previous edition D 4060 - 84.

² Annual Book of ASTM Standards, Vol 06.01

³ Annual Book of ASTM Standards, Vol 09.01.

⁴ Available from Teledyne Taber, North Tonawanda, NY 14120.

each panel. Prepare a minimum of two coated panels for the

NOTE 4—The thickness of the dry coatings should be measured in accordance with Test Methods D 1005, D 1186, or D 1400.

8. Standardization

8.1 Mount the selected abrasive wheels on their respective flange holders, taking care not to handle them by their abrasive surfaces. Adjust the load on the wheels to 1000 g.

8.2 Mount the resurfacing medium (S-11 abrasive disk) on the turntable. Lower the abrading heads carefully until the wheels rest squarely on the abrasive disk. Place the vacuum pick-up nozzle in position and adjust it to a distance of 1/32 in. (1 mm) above the abrasive disk.

8.3 Set the counter to "zero" and set the suction regulator to approximately 50 points on the dial. The setting may be increased to 90 if more effective removal of the abrasings appears necessary.

8.4 Start the vacuum pick-up and then the turntable of the abrader. Resurface the wheels by running them 50 cycles against the resurfacing medium.

NOTE 5—The wheels should be resurfaced in this manner before testing each specimen and after every 500 cycles.

9. Conditioning

9.1 Cure the coated panel under conditions of humidity and temperature as agreed upon between purchaser and seller.

Unless otherwise agreed upon between purchaser and seller, condition the coated panel for at least 24 h at 23 ± 2°C and 50 ± 5 % relative humidity. Conduct the test in the same environment or immediately on removal therefrom.

10. Procedure

10.1 Weigh the test specimen to the nearest 0.1 mg and record this weight, if either the wear index or the weight loss is to be reported.

10.2 Measure the coating thickness of the test specimen in several locations along the path to be abraded.

10.3 Mount the test specimen on the turntable. Place the abrading heads on the test film and the vacuum pick-up nozzle in position as outlined in 8.2. Set the counter and suction regulator as outlined in 8.3.

10.4 Start the vacuum pick-up and then the turntable of the abrader. Subject the test specimen to abrasion for the specified number of cycles or until wear through of the coating is observed. In determining the point of wear through, stop the instrument at intervals for examination of the test specimen.

10.5 Remove any loose abrasings remaining on the test specimen by light brushing. Reweigh the test specimen.

10.6 Repeat 10.1 to 10.5 on at least one additional test specimen of the material under test.

11. Calculation

11.1 *Wear Index*—Compute the wear index, I , of a test specimen as follows:

$$I = \frac{(A - B) 1000}{C}$$

where:

A = weight of test specimen before abrasion, mg.

B = weight of test specimen after abrasion, mg. and

C = number of cycles of abrasion recorded.

NOTE 6—In calculating wear index it may be advisable to discard the last 200 cycles because the results may be affected by abrasion of the exposed substrate.

11.2 *Weight Loss*—Compute weight loss, L , of the test specimen as follows:

$$L = A - B$$

where:

A = weight of test specimen before abrasion, mg. and

B = weight of test specimen after abrasion, mg.

11.3 *Wear Cycles Per Mil*—Compute the wear cycles per mil, W , of the test specimen as follows:

$$W = D/T$$

where:

D = number of cycles of abrasion required to wear coating through to substrate and

T = thickness of coating, mils (0.001 in.) (to one decimal place).

NOTE 7—In calculating the wear cycles, it is advisable to discard the first and last readings because the first may be affected by an uneven surface and the last by abrasion of parts of the substrate.

12. Report

12.1 Report the following information for each test material:

12.1.1 Temperature and humidity during conditioning and at the time of testing,

12.1.2 Thickness of coating when wear cycles are specified,

12.1.3 Kind of calibrase abrasive wheels used,

12.1.4 Load applied to the abrasive wheels,

12.1.5 Number of wear cycles recorded for each test specimen,

TABLE 1 Precision of Taber Abrasion Values

	Within Laboratory		Between Laboratories	
	Coefficient of Variation, %	Maximum Allowable Difference, %	Coefficient of Variation, %	Maximum Allowable Difference, %
Weight loss at 500 cycles	12	48	36	105
Weight loss at 1000 cycles	10	46	30	90
Wear index at 500 cycles	13	52	36	106
Wear index at 1000 cycles	10	46	30	92
Cycles per mil	13	44	31	92

12.1.6 Wear index, weight loss, or wear cycles per mil for each test specimen, and

12.1.7 Mean and range of the abrasion resistance values of the replicate coated panels.

13. Precision⁵

13.1 On the basis of an interlaboratory test of this test method in which operators in five laboratories tested four coatings having a broad range of abrasion resistance, the within-laboratory coefficients of variation and between-laboratories coefficients of variation were found to be those in Table 1. Based upon these coefficients, the following

criteria should be used for judging the acceptability of results at the 95 % confidence level:

13.1.1 *Repeatability*—Two results by the same operator should be considered suspect if they differ by more than the maximum allowable difference values shown in Table 1.

13.1.2 *Reproducibility*—Two results obtained by operators in different laboratories should be considered suspect if they differ by more than the maximum allowable difference values shown in Table 1.

NOTE 8—When this test method is used to rank a series of coatings by magnitude of abrasion resistance, the precision is significantly better than shown in Table 1. In the interlaboratory study for evaluating precision, all laboratories ranked the coatings in the same order of abrasion resistance.

14. Keywords

14.1 wear index

⁵ Supporting data are available from ASTM Headquarters. Request RR D01-1037.

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The cross-cut test is a simple and easily practicable method for evaluating the adhesion of single- or multi-coat systems.

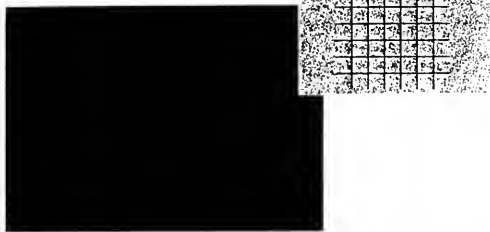
Procedure

- Make a lattice pattern in the film with the appropriate tool, cutting to the substrate
- Brush in diagonal direction 5 times each, using a brush pen or tape over the cut and remove with Permaceal tape
- Examine the grid area using an illuminated magnifier

Cross-Cut Results

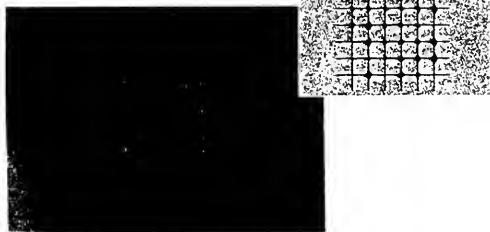
Adhesion is rated in accordance with the scale below.

■ ISO Class.: 0 / ASTM Class.: 5 B



The edges of the cuts are completely smooth; none of the squares of the lattice is detached.

■ ISO Class.: 1 / ASTM Class.: 4 B



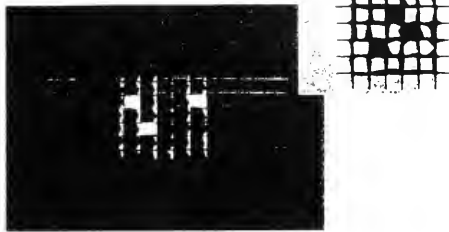
Detachment of small flakes of the coating at the intersections of the cuts. A cross-cut area not significantly greater than 5 % is affected.

■ ISO Class.: 2 / ASTM Class.: 3 B



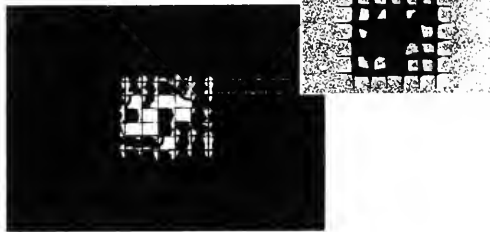
The coating has flaked along the edges and/or at the intersections of the cuts. A cross-cut area significantly greater than 5 %, but not significantly greater than 15 %, is affected.

■ ISO Class.: 3 / ASTM Class.: 2 B



The coating has flaked along the edges of the cuts partly or wholly in large ribbons, and/or it has flaked partly or wholly on different parts of the squares. A cross-cut area significantly greater than 15 %, but not significantly greater than 35 %, is affected.

■ ISO Class.: 4 / ASTM Class.: 1 B



The coating has flaked along the edges of the cuts in large ribbons and/or some squares have detached partly or wholly. A cross-cut area significantly greater than 35 %, but not significantly greater than 65 %, is affected.

■ ISO Class.: 5 / ASTM Class.: 0 B

Any degree of flaking that cannot even be classified by classification 4.

Standards

ASTM D 3002 D 3359

DIN 53 151*

DIN EN ISO 2409

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*DIN 53151 was withdrawn in October 1994

Standard Test Methods for Measuring Adhesion by Tape Test¹

This standard is issued under the fixed designation D 3359; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

These methods have been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 These test methods cover procedures for assessing the adhesion of coating films to metallic substrates by applying and removing pressure-sensitive tape over cuts made in the film.

1.2 Test Method A is primarily intended for use at job sites while Test Method B is more suitable for use in the laboratory. Also, Test Method B is not considered suitable for films thicker than 5 mils (125 μm).

NOTE 1—Subject to agreement between the purchaser and the seller, Test Method B can be used for thicker films if wider spaced cuts are employed.

1.3 These test methods are used to establish whether the adhesion of a coating to a substrate is at a generally adequate level. They do not distinguish between higher levels of adhesion for which more sophisticated methods of measurement are required.

NOTE 2—It should be recognized that differences in adherability of the coating surface can affect the results obtained with coatings having the same inherent adhesion.

1.4 In multicoat systems adhesion failure may occur between coats so that the adhesion of the coating system to the substrate is not determined.

1.5 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

D 609 Methods for Preparation of Steel Panels for Testing Paint, Varnish, Lacquer, and Related Products²

D 823 Test Methods for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels²

D 1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting³

D 2092 Practices for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting²

D 2370 Test Method for Tensile Properties of Organic Coatings²

D 3330 Test Method for Peel Adhesion of Pressure-Sensitive Tape of 180° Angle⁴

D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser²

3. Summary of Test Methods

3.1 *Test Method A*—An X-cut is made in the film to the substrate, pressure-sensitive tape is applied over the cut and then removed, and adhesion is assessed qualitatively on the 0 to 5 scale.

3.2 *Test Method B*—A lattice pattern with either six or eleven cuts in each direction is made in the film to the substrate, pressure-sensitive tape is applied over the lattice and then removed, and adhesion is evaluated by comparison with descriptions and illustrations.

4. Significance and Use

4.1 If a coating is to fulfill its function of protecting or decorating a substrate, it must adhere to it for the expected service life. Because surface preparation (or lack of it) has a drastic effect on adhesion of coatings, a test method for evaluating adhesion to different surface treatments or of different coatings to the same treatment is of considerable use in the industry.

4.2 The limitations of all adhesion methods and the specific limitation of this test method to lower levels of adhesion (see 1.3) should be recognized before using it. The intra- and inter-laboratory precision of this test method is similar to other widely-accepted tests for coated substrates (for example, Test Method D 2370 and Test Method D 4060), but this is partly the result of it being insensitive to all but large differences in adhesion. The limited scale of 0 to 5 was selected deliberately to avoid a false impression of being sensitive.

TEST METHOD A—X-CUT TAPE TEST

5. Apparatus and Materials

5.1 *Cutting Tool*—Sharp razor blade, scalpel, knife or other cutting devices. It is of particular importance that the

¹ These test methods are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and are the direct responsibility of Subcommittee D01.23 on Physical Properties of Applied Paint Films.

Current edition approved Oct. 26, 1990. Published December 1990. Originally published as D 3359 - 74. Last previous edition D 3359 - 87.

² Annual Book of ASTM Standards, Vol 06.01.

³ Annual Book of ASTM Standards, Vols 02.05 and 06.06.

⁴ Annual Book of ASTM Standards, Vol 15.09.

⁵ Permacel 99 manufactured by Permacel, New Brunswick, NJ 08903, and available from various Permacel tape distributors, is reported to be suitable for this purpose. The manufacturer of this tape and the manufacturer of the tape used in the interlaboratory study⁴ have advised this subcommittee that the properties of these tapes were changed. Users of it should, therefore, check whether current material gives comparable results to previous supplied material.

cutting edges be in good condition.

5.2 *Cutting Guide*—Steel or other hard metal straightedge to ensure straight cuts.

5.3 *Tape*—One-inch (25-mm) wide semitransparent pressure-sensitive tape with an adhesion strength agreed upon by the supplier and the user is needed. Because of the variability in adhesion strength from batch-to-batch and with time, it is essential that tape from the same batch be used when tests are to be run in different laboratories. If this is not possible the test method should be used only for ranking a series of test coatings.

5.4 *Rubber Eraser*, on the end of a pencil.

5.5 *Illumination*—A light source is helpful in determining whether the cuts have been made through the film to the substrate.

6. Test Specimens

6.1 When this test method is used in the field, the specimen is the coated structure or article on which the adhesion is to be evaluated.

6.2 For laboratory use apply the materials to be tested to panels of the composition and surface conditions on which it is desired to determine the adhesion.

NOTE 3—Applicable test panel description and surface preparation methods are given in Methods D 609 and Practices D 1730 and D 2092.

NOTE 4—Coatings should be applied in accordance with Test Methods D 823, or as agreed upon between the purchaser and the seller.

NOTE 5—If desired or specified, the coated test panels may be subjected to a preliminary exposure such as water immersion, salt spray, or high humidity before conducting the tape test. The conditions and time of exposure will be governed by ultimate coating use or shall be agreed upon between the purchaser and seller.

7. Procedure

7.1 Select an area free of blemishes and minor surface imperfections. For tests in the field, ensure that the surface is clean and dry. Extremes in temperature or relative humidity may affect the adhesion of the tape or the coating.

7.2 Make two cuts in the film each about 1.5 in. (40 mm) long that intersect near their middle with a smaller angle of between 30 and 45°. When making the incisions, use the straightedge and cut through the coating to the substrate in one steady motion.

7.3 Inspect the incisions for reflection of light from the metal substrate to establish that the coating film has been penetrated. If the substrate has not been reached make another X in a different location. Do not attempt to deepen a previous cut as this may affect adhesion along the incision.

7.4 Remove two complete laps of the pressure-sensitive tape from the roll and discard. Remove an additional length at a steady (that is, not jerked) rate and cut a piece about 3 in. (75 mm) long.

7.5 Place the center of the tape at the intersection of the cuts with the tape running in the same direction as the smaller angles. Smooth the tape into place by finger in the area of the incisions and then rub firmly with the eraser on the end of a pencil. The color under the transparent tape is a useful indication of when good contact has been made.

7.6 Within 90 ± 30 s of application, remove the tape by pulling the free end and pulling it off rapidly (not jerked) upon itself at as close to an angle of 180° as possible.

7.7 Inspect the X-cut area for removal of coating from the

substrate or previous coating and rate the adhesion in accordance with the following scale:

- 5A No peeling or removal.
- 4A Trace peeling or removal along incisions or at their intersection.
- 3A Jagged removal along incisions up to $\frac{1}{16}$ in. (1.6 mm) on either side.
- 2A Jagged removal along most of incisions up to $\frac{1}{8}$ in. (3.2 mm) on either side.
- 1A Removal from most of the area of the X under the tape.
- 0A Removal beyond the area of the X.

7.8 Repeat the test in two other locations on each test panel. For large structures make sufficient tests to ensure that the adhesion evaluation is representative of the whole surface.

7.9 After making several cuts examine the cutting edge and, if necessary, remove any flat spots or wire-edges by abrading lightly on a fine oil stone before using again. Discard cutting tools that develop nicks or other defects that may tear the film.

8. Report

8.1 Report the number of tests, their mean and range, and for coating systems, where the failure occurred and at what time between first coat and substrate, between first and second coat, etc.

8.2 For field tests report the structure or article tested, the location and the environmental conditions at the time of testing.

8.3 For test panels report the substrate employed, the type of coating, the method of cure, and the environmental conditions at the time of testing.

8.4 If the adhesion strength of the tape has been determined in accordance with Test Method D 3330, report the results with the adhesion rating(s).

9. Precision and Bias⁶

9.1 In an interlaboratory study of this test method in which operators in six laboratories made one adhesion measurement on three panels each of three coatings covering a wide range of adhesion, the within-laboratories standard deviation was found to be 0.33 and the between-laboratories 0.44. Based on these standard deviations, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

9.1.1 *Repeatability*—Provided adhesion is uniform over a large surface, results obtained by the same operator should be considered suspect if they differ by more than 1 rating unit for two measurements.

9.1.2 *Reproducibility*—Two results, each the mean of triplicates, obtained by different operators should be considered suspect if they differ by more than 1.5 rating units.

9.2 Bias cannot be established for these test methods.

TEST METHOD B—CROSS-CUT TAPE TEST

10. Apparatus and Materials

10.1 *Cutting Tool*—Sharp razor blade, scalpel, knife or other cutting device having a cutting edge or edges angled

⁶ Supporting data are available from ASTM Headquarters. Request RR D01-1008.

5 and 30° that will make either a single cut or at once. It is of particular importance that the cutting edge be in good condition.

12.2 *Cutting Guide*—If cuts are made manually (as opposed to a mechanical apparatus) a steel or other hard metal edge or template to ensure straight cuts.

12.3 *Rule*—Tempered steel rule graduated in 0.5 mm for measuring individual cuts.

12.4 *Tape*, as described in 5.3.

12.5 *Rubber Eraser*, on the end of a pencil.

12.6 *Illumination*, as described in 5.5.

12.7 *Magnifying Glass*—An illuminated magnifier to be used while making individual cuts and examining the test

Test Specimens

Test specimens shall be as described in Section 6.

Procedure

12.1 Where required or when agreed upon, subject the specimens to a preliminary test before conducting the tape test (see Note 3). After drying or testing, select an area free of finishes and minor surface imperfections.

12.2 Place the panel on a firm base and under the illuminated magnifier make parallel cuts as follows:

12.2.1 For coatings having a dry film thickness up to and including 2.0 mils (50 μ m) space the cuts 1 mm apart and make eleven cuts unless otherwise agreed upon.

12.2.2 For coatings having a dry film thickness between 2.0 mils (50 μ m) and 5 mils (125 μ m), space the cuts 2 mm apart and make six cuts. For films thicker than 5 mils use Test Method A.

12.2.3 Make all cuts about 3/4 in. (20 mm) long. Cut through the film to the substrate in one steady motion using just sufficient pressure on the cutting tool to have the cutting edge reach the substrate. When making successive single cuts with the aid of a guide, place the guide on the uncut area.

12.3 After making the required cuts brush the film lightly with a soft brush or tissue to remove any detached flakes or ribbons of coatings.

12.4 Examine the cutting edge and, if necessary, remove any flat spots or wire-edge by abrading lightly on a fine oil stone. Make the additional number of cuts at 90° to and centered on the original cuts.

12.5 Brush the area as before and inspect the incisions for reflection of light from the substrate. If the metal has not been reached make another grid in a different location.

12.6 Remove two complete laps of tape and discard. Remove an additional length at a steady (that is, not jerked) rate and cut a piece about 3 in. (75 mm) long.

12.7 Place the center of the tape over the grid and in the area of the grid smooth into place by a finger. To ensure good contact with the film rub the tape firmly with the eraser on the end of a pencil. The color under the tape is a useful indication of when good contact has been made.

12.8 Within 90 \pm 30 s of application, remove the tape by pulling the free end and rapidly (not jerked) pulling it off at close to an angle of 180° as possible.

12.9 Inspect the grid area for removal of coating from the substrate or from a previous coating using the illuminated magnifier. Rate the adhesion in accordance with the fol-

lowing scale illustrated in Fig. 1:

- 5B The edges of the cuts are completely smooth: none of the squares of the lattice is detached
- 4B Small flakes of the coating are detached at intersections, less than 5 % of the area is affected.
- 3B Small flakes of the coating are detached along edges and at intersections of cuts. The area affected is 5 to 15 % of the lattice.
- 2B The coating has flaked along the edges and on parts of the squares. The area affected is 15 to 35 % of the lattice.
- 1B The coating has flaked along the edges of cuts in large ribbons and whole squares have detached. The area affected is 35 to 65 % of the lattice.
- 0B Flaking and detachment worse than Grade 1.

12.10 Repeat the test in two other locations on each test panel.

13. Report

13.1 Report the number of tests, their mean and range, and for coating systems, where the failure occurred, that is, between first coat and substrate, between first and second coat, etc.

13.2 Report the substrate employed, the type of coating and the method of cure.

13.3 If the adhesion strength of the tape has been determined in accordance with Test Method D 3330, report the

Classification of Adhesion Test Results





Classification	Surface of cross-cut area from which flaking has occurred. (Example for six parallel cuts)
5B	None
4B	
3B	
2B	
1B	
0B	Greater than 65%

FIG. 1 Classification of Adhesion Test Results

results with the adhesion rating(s).

14. Precision and Bias⁶

14.1 On the basis of two interlaboratory tests of this test method in one of which operators in six laboratories made one adhesion measurement on three panels each of three coatings covering a wide range of adhesion and in the other operators in six laboratories made three measurements on two panels each of four different coatings applied over two other coatings, the pooled standard deviations for within- and between-laboratories were found to be 0.37 and 0.7.

Based on these standard deviations, the following c_{95} should be used for judging the acceptability of results at 95 % confidence level:

14.1.1 *Repeatability*—Provided adhesion is uniform over a large surface, results obtained by the same operator should be considered suspect if they differ by more than one rating unit for two measurements.

14.1.2 *Reproducibility*—Two results, each the mean of duplicates or triplicates, obtained by different operators should be considered suspect if they differ by more than two rating units.

14.2 Bias cannot be established for these test methods.

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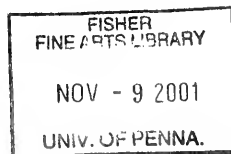
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